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TEC, SCOTEC & CGLI: GUIDANCE FOR STUDENTS

Contents

CITY AND GUILDS OF LONDON INSTITUTE

Questions and Answers

Answers are occasionally omitted or reference is made to earlier Supplements in which questions of substantially the same form, together with answers, have been published. Some answers contain more detail than would be expected from candidates under examination conditions.

TELEGRAPHY C 1981 *(continued)*

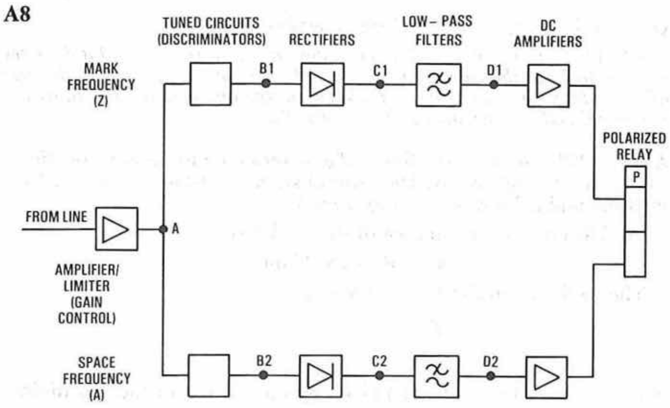
Q8 (a) For a channel receiver of a multi-channel voice-frequency (MCVF) system

(i) draw a block diagram,
(ii) sketch the signal waveforms at significant points, and
(iii) explain its operation.

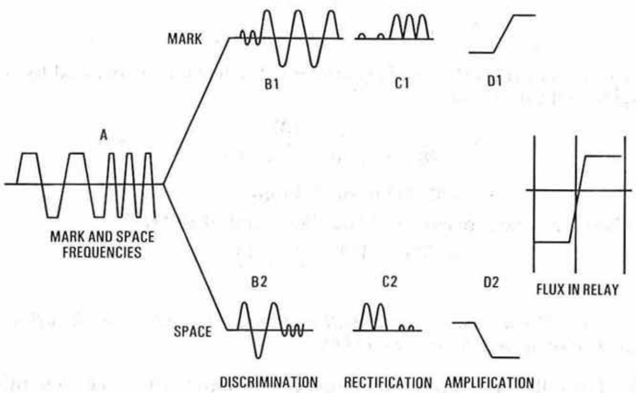
(b) For a high-capacity MCVF system, tabulate, for 50, 100 and 200-baud channels

(i) the channel spacing,
(ii) the mean frequencies, and
(iii) the frequency shift.

A8



(*a*)



(*b*)

(*a*) (*i*) Sketch (*a*) shows a block diagram of a channel receiver of a MCVF system.

(*ii*) Signal waveforms at significant points in the system are shown in sketch (*b*).

(*iii*) Incoming signals are of the FSK (frequency shift keying) type. A nominal carrier frequency has been changed in one direction for a *mark* signal and in the other direction for a *space* signal.

Initial amplification and limiting provide signals of the required amplitude for the receiver, and ensure that all signals are of equal amplitude, thus eliminating any line noise which has caused amplitude variations (point A in sketches (*a*) and (*b*)).

Two separate tuned circuits act as discriminators, one selecting the *mark* frequency and the other, the *space* frequency (point B). The discriminated signals are then rectified (point C) and DC amplified (point D) before being passed to the polarized relay, where the originally transmitted telegraph signals of that channel are reproduced.

(*b*)

Modulation Rate	50 baud	100 baud	200 baud
(*i*) Channel Spacing	120 Hz	240 Hz	480 Hz
(*ii*) Mean Frequencies	420 Hz, 540 Hz, etc. in 120 Hz steps	480 Hz, 720 Hz, etc. in 240 Hz steps	600 Hz, 1080 Hz, etc. in 480 Hz steps
(*iii*) Frequency Shift	30 Hz	60 Hz	120 Hz

Q9 For an automatic routiner in a Telex exchange, describe, with the aid of diagrams

(a) how access is gained to the equipment to be tested,

(b) how faults are recorded,

(c) how the routiner is started and stopped automatically, and

(d) the facilities which are offered by the control panel.

A9 (*a*), (*b*) and (*c*) See A1 (*a*) and (*b*), Telegraphy C 1979, *Supplement*, Vol. 73, p. 20, Apr. 1980.

(*d*) The routiner facilities are as follows:

(*i*) controls for starting and stopping the series of tests;
(*ii*) indicators showing which rack, shelf and particular item of equipment is being tested;
(*iii*) lamps indicating which particular test is taking place;
(*iv*) control for test repetitions (such as relay timing);

(*v*) facility for manual selection of tests to be carried out;
(*vi*) controls to provide continuous routining;
(*vii*) indication that a fault has been found; and
(*viii*) alarms to indicate that a fault has been found and that the routiner has stopped running tests.

Q10 (*a*) *Describe, with the aid of a block diagram, the operation of international Telex switchboard equipment on receiving a call from an inland subscriber.*

(*b*) *How is the subscriber charged for a call*

(*i*) *over a cable route, and*
(*ii*) *over an ARQ-protected radio circuit?*

(*c*) *What are the charging procedures for a call routed automatically through a gateway exchange using automatic ticketing equipment?*

A10 (*a*) See A6, Telegraphy C 1978, *Supplement*, Vol. 72, p. 45, July 1979.

(*b*) (*i*) The operator of the international Telex switchboard obtains the answer-back codes from the calling subscriber and the called subscriber in turn. The operator checks that the correct connection has been made, puts the call through, and starts the switchboard timer associated with the connecting circuit. The timer operates from meter pulses at 6 s intervals. The operator records the calling subscriber's identity together with the called subscriber's number on a ticket or docket. The connection is cleared by either subscriber and this automatically stops the timer. The operator notes the elapsed time on the ticket and resets the timer.

(*ii*) For ARQ-protected circuits, the call is set up in a similar manner to a cable route, but the timer is controlled from the ARQ equipment. The timer is not pulsed during periods of poor radio conditions.

Calls from a cable route, through an automatic transit exchange, to an ARQ circuit cause problems, as the originating exchange charges the subscriber according to elapsed time. In these circumstances, the International Telegraph and Telephone Consultative Committee (CCITT) recommends certain precautions. CCITT Recommendation U23 states that if in the course of an established connection, the efficiency of the radio circuit drops below 80% over a period of 60 consecutive seconds, then the connection is to be released. This ensures that the subscriber is not overcharged for an inefficient radio circuit.

(*c*) A typical computer-controlled Telex exchange records brief details of all calls processed by the exchange. A magnetic tape is made of this record and passed to the Data Processing Department for billing purposes. For each successful call, the record contains the calling and called subscribers' numbers, the times when the call is set up and cleared, the date, the trunk used, and whether the call was selected automatically, or with an operator's assistance. From this information, the Data Processing Department is able to establish the minimum billing time: 1 min for automatically selected calls and 3 min for calls requiring operator assistance (rounding up to the nearest minute). Tariffs can be obtained from the destination code dialled. The call is billed to the calling subscriber.

For international accounts, note is made of the trunk used. Transit and terminal exchanges can then be credited with the appropriate charges.

LINE PLANT PRACTICE C 1981

Students were expected to answer any 6 questions

Q1 (*a*) *Describe, with the aid of diagrams, the manner in which an AC electric railway can interfere with circuits in a nearby telephone cable.*

(*b*) *Explain briefly how the interference is reduced by*

(*i*) *the rails, and*
(*ii*) *the introduction of booster transformers.*

Q2 (*a*) *State and describe briefly the* THREE *main groups into which natural rock is divided.*

(*b*) *State and describe the* FIVE *main fractions into which a mineral soil is divided.*

(*c*) *What is moisture unstable soil?*

A2 See A5, Line Plant Practice C, 1975, *Supplement*, Vol. 69, p. 82, Jan. 1977.

Q3 *A pole route consists of 8·5 m poles set 1·4 m into the ground and spaced at 65 m apart. An aerial cable is to be erected on the poles and supported in brackets mounted 0·65 m from the top of the poles. The safe moment of resistance of a pole is 15·5 kNm.*

(*a*) *What would be the maximum diameter of the aerial cable erected, if the relation between the wind pressure and diameter of cable is given by $P = 0{\cdot}358d$ per metre, where P is in newtons and d is in millimeters?*

(*b*) *Calculate the wind pressure on one span of cable.*

A3 (*a*) The force acting on a pole is the wind pressure acting on half a span either side of the pole.

Therefore, the force on the pole

$$= 0{\cdot}358d \times 65 \text{ N}.$$

The moment of this force on the pole

$$= 0{\cdot}358d \times 65 \times (8{\cdot}5 - 1{\cdot}4 - 0{\cdot}65),$$
$$= 0{\cdot}358d \times 65 \times 6{\cdot}45 \text{ Nm}.$$

But, the safe moment of resistance of the pole is 15·5 kNm.
Thus, equating gives

$$15{\cdot}5 \times 10^3 = 0{\cdot}358 \times 65 \times 6{\cdot}45d.$$

Therefore, the maximum diameter of aerial cable is

$$\frac{15{\cdot}5 \times 10^3}{0{\cdot}358 \times 65 \times 6{\cdot}45} = \underline{103 \text{ mm.}}$$

(*b*) The wind pressure on one span of 103 mm diameter cable

$$= 0{\cdot}358 \times 103 \times 65 \text{ N},$$
$$= \underline{2{\cdot}4 \text{ kN.}}$$

Q4 (*a*) *What is meant by Young's modulus?*

(*b*) *A steel rod, 6 mm in diameter, operates a railway signal a distance of 1000 m from the signal box. A pull of 2 kN moves the rod a distance of 580 mm at the operating end. Calculate the distance the rod moves at the signal end. E_S for steel is 200×10^9 Pa.*

A4 (*a*) Within the elastic limits of a material the strain is proportional to the stress producing it. The ratio of stress to strain is constant for a material and is known as *Young's modulus*.

(*b*) The cross-sectional area of the steel rod

$$= \pi \times 3^2 = 28{\cdot}27 \text{ mm}^2.$$

The strain, *e*, on the rod is given by

$$e = \frac{f}{E_S},$$

where *f* is the stress (pascals) given by the tension in the rod divided by its cross-sectional area.

$$\therefore \quad e = \frac{2 \times 10^3}{28{\cdot}27 \times 10^{-6} \times 200 \times 10^9}.$$

But, the strain in the rod is given by the extension, *x*, divided by the original length, so that

$$x = \frac{2 \times 10^3}{28{\cdot}27 \times 10^{-6} \times 200 \times 10^9} \times 1000,$$
$$= 0{\cdot}354 \text{ m or } 354 \text{ mm}.$$

Therefore, the movement at the signal end of the rod

$$= 580 - 354 = \underline{226 \text{ mm.}}$$

Q5 *Describe a Single-Ended Fall-of-Potential method of locating a dielectric fault in a submarine cable.*

A5 The fall-of-potential test involves determining the fall of potential encountered between one end of the cable and the fault. Knowledge

of this, and the testing current applied, enables the resistance to the fault, X, to be determined. The potential at the fault, V_B, can be accurately measured since there is no leakage through the dielectric beyond the fault; therefore, the potential at the fault is equal to the potential measured at the distant station (see sketch).

The testing circuit consists of a stabilized power supply connected in series with a 1 kΩ or 10 kΩ standard resistor (M), and connected between the cable centre conductor and earth. V_C is measured with a digital voltmeter while a known current is fed into the cable (usually 5 mA), which returns via the fault resistance and earth. The power supply is switched off, the cable is discharged at both ends, the test current is then applied, and the potentials at the 2 ends of the cable, V_A and V_B are measured simultaneously. The simultaneous readings reduce the effect of any changes in earth potentials and fault resistance.

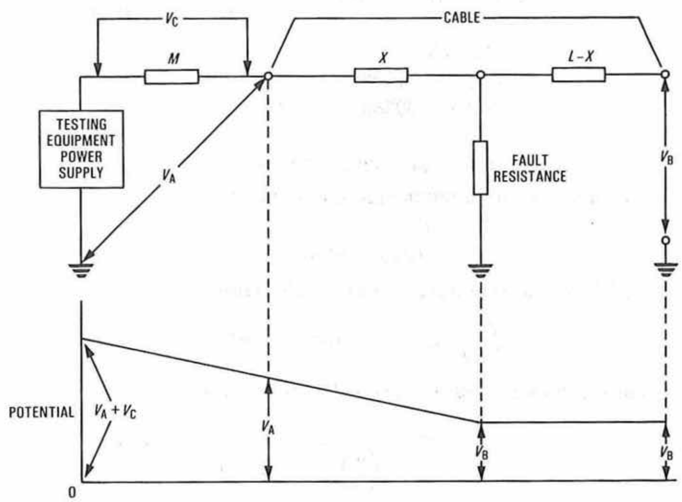
After the potential gradient shown in the sketch has been established, the value of X is determined from the equation

$$X = \frac{(V_A - V_B)M}{V_C}\ \Omega.$$

The value of X represents the resistance of the system to the fault at the value of testing current used.

If the test is repeated at the far end of the cable at the same testing current, the values of X and $L - X$ give the total cable system resistance L at the testing current used.

The tests are repeated by using the opposite polarity of testing current, and the most stable and consistent results are taken for the final result.



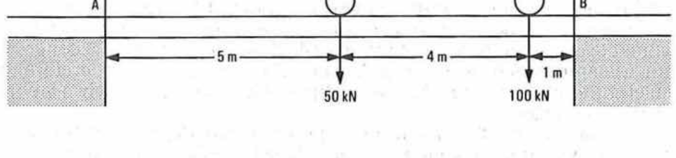
Q6 A 4-wheeled vehicle, with a wheel base of 4 m and front and rear axle loads of 50 kN and 100 kN respectively, crosses a freely supported bridge having a span of 10 m. At the time the front wheels of the lorry reach the centre of the span

(*a*) *draw a shear force diagram,*

(*b*) *draw a bending moment diagram, and*

(*c*) *what is the bending moment at the centre of the span?*

A6 (*a*)

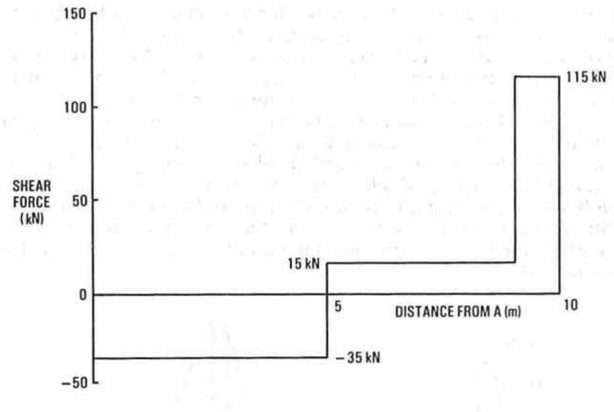


The forces, R_A and R_B, which represent the supports at each end of the bridge, are calculated by taking moments about A.

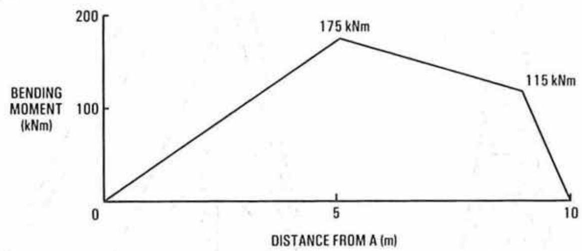
Thus, $10 \times R_B = 50 \times 5 + 100 \times 9.$

$\therefore\quad R_B = 115$ kN,

and, $R_A = 100 + 50 - 115 = 35$ kN.



(*b*)



(*c*) The bending moment at C

$= 5 \times R_A = \underline{175 \text{ kN}}.$

Q7 With the aid of a labelled block diagram, describe the operation of an adsorption type of compressor-desiccator for use in a continuous flow gas pressurization system.

A7 See A1, Line Plant Practice C 1975, *Supplement*, Vol. 69, p. 81, Jan. 1977.

Q8 (*a*) *Describe, with the aid of sketches, a suitable aerial support structure for use with*

(*i*) *a microwave aerial, and*

(*ii*) *a low-frequency aerial array.*

(*b*) *A section of a guyed mast is shown in Fig. 1. The legs are 100 mm × 100 mm equal angle and the bracings are 50 mm × 50 mm equal angle. If the force coefficient of the section C = 2·3 calculate the wind force on the section for a 50 m/s wind velocity. Force =0·614 V^2CA.*

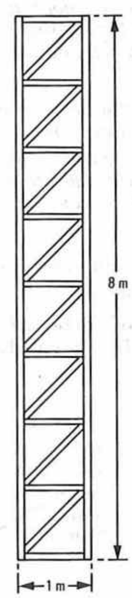
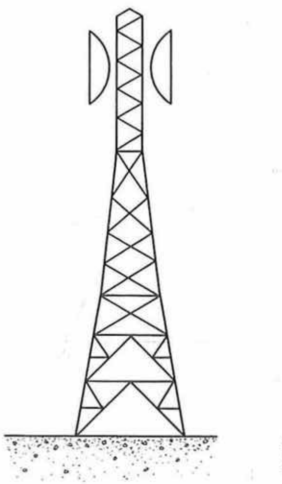


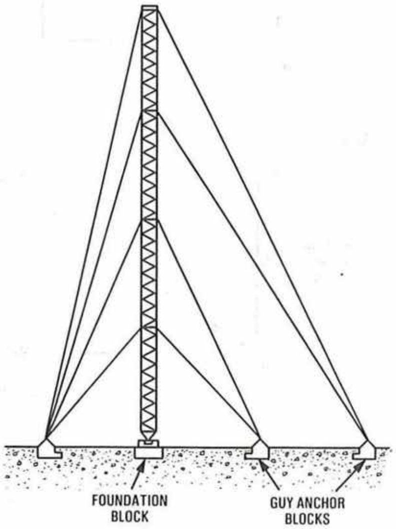
Fig. 1

A8 (*a*) (*i*) A lattice steel tower of either welded or bolted construction, as shown in sketch (*a*), is suitable for supporting a microwave aerial. The lattice steel tower has corner legs held apart by shear bracings with plan bracings to give sectional stability to the structure. The height-to-base ratio is usually of the order of 6 or 7 to 1.

(*ii*) A guyed mast system can be used to support a low-frequency aerial array. The construction is usually of lattice steel and either bolted or welded. A narrow parallel-sided structure, of either square or triangular section, which is supported at its base on a suitable foundation, can be used. Guys are used to hold the mast in the vertical position; these are attached to the mast at intervals and are anchored at their ground ends to guy anchor blocks. A typical mast is shown in sketch (*b*).



(*a*)



(*b*)

(*b*) The total area of section presented to the wind force is calculated as follows.

Area of legs $= 2 \times 8 \times 0{\cdot}1 = 1{\cdot}6$ m^2.

Approximate area of horizontal bracing
$= 9 \times 1 \times 0{\cdot}05 = 0{\cdot}45$ m^2.

Approximate area of diagonal bracing
$= 8 \times \sqrt{2} \times 0{\cdot}05 = 0{\cdot}57$ m^2.

Total area $= 2{\cdot}62$ m^2.

Thus, force on the section
$= 0{\cdot}614 \times 50^2 \times 2{\cdot}3 \times 2{\cdot}62 = \underline{9250\text{ N.}}$

Q9 (*a*) *A cable is to be pulled into a duct A–B. The duct runs from A 80 m horizontally then bends round a short 30° arc followed by a straight run up a slope for 185 m, rising by 8 m. The remaining 45 m is horizontal to B. Cable weighs 6 kg/m. Coefficient of friction is 0·4.*

Calculate

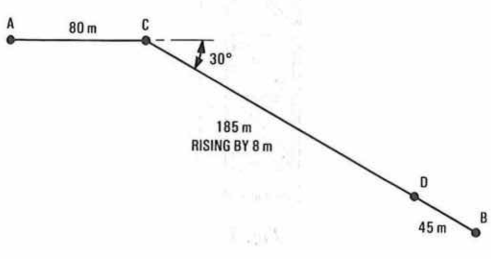
(*i*) *the tension if cable is drawn A–B, and*
(*ii*) *the tension if cable is drawn B–A.*

(*b*) *Derive a relation between the limiting pull in newtons (N) on a cable, the number of pairs (n) and the diameter (d) in millimetres of* EACH *conductor, if the stress on the conductor material must not exceed 30 MPa.*

A9 (*a*) (*i*) The pulling tension in section AC is given by,

$$T_{AC} = \mu l w \text{ newtons,}$$

where μ is the coefficient of friction, l is the length of the section (metres), and w is the weight per unit length of the cable (newtons/metre),



$$= 0{\cdot}4 \times 80 \times 60 = 1920 \text{ N.}$$

The pulling tension at bend C is given by

$$T_C = T_{AC} e^{\mu\theta} \text{ newtons,}$$

where θ is the angle of the arc (rad),

$$= 1920 \times e^{0\cdot4\times0\cdot524} = 1920 \times 1{\cdot}2332 = 2368 \text{ N.}$$

The pulling tension up gradient CD is given by

$$T_{CD} = wl\,(\mu \cos\phi + \sin\phi) \text{ newtons,}$$

where ϕ is the angle of the slope.

$$\sin\phi = \frac{8}{185} \text{ and } \cos\phi = \frac{\sqrt{(185^2 - 8^2)}}{185}.$$

$$\therefore \quad T_{CD} = 60 \times 185 \times \left\{0{\cdot}4 \times \frac{\sqrt{(185^2 - 8^2)}}{185} + \frac{8}{185}\right\},$$

$$= 4916 \text{ N.}$$

The pulling tension in section DB is given by

$$T_{DB} = 0{\cdot}4 \times 45 \times 60 = 1080 \text{ N.}$$

Therefore, the total pulling tension in direction A–B

$$= T_C + T_{CD} + T_{DB} \text{ newtons,}$$
$$= 2368 + 4916 + 1080 = \underline{8364 \text{ N.}}$$

(*ii*) $T_{BD} = 1080$ N.

$$T_{DC} = wl\,(\mu\cos\phi - \sin\phi),$$

$$= 60 \times 185 \times \left\{0{\cdot}4 \times \frac{\sqrt{(185^2 - 8^2)}}{185} - \frac{8}{185}\right\},$$

$$= 3956 \text{ N.}$$

$$T_C = (T_{BD} + T_{DC})e^{\mu\theta},$$
$$= (1080 + 3956)e^{0\cdot4\times0\cdot524},$$
$$= 6210 \text{ N.}$$
$$T_{CA} = 0{\cdot}4 \times 80 \times 60 = 1920 \text{ N.}$$

Therefore, the total pulling tension in direction B–A

$$= T_{CA} + T_C,$$
$$= 1920 + 6210 = \underline{8130 \text{ N.}}$$

(*b*) The cross-sectional area of the cable core

$$= \left(\frac{d}{2}\right)^2 \pi n \times 2 \times 10^{-6} \text{ metre}^2.$$

The maximum stress on the conductor material

$$= 30 \times 10^6 = \frac{N}{\left(\frac{d}{2}\right)^2 \pi n \times 2 \times 10^{-6}} \text{ pascals.}$$

$$\therefore \quad N = \frac{30\pi d^2 n}{2} = 15\pi d^2 n.$$

$$= \underline{47{\cdot}12 d^2 n \text{ newtons.}}$$

Q10 (*a*) *Explain the meaning of the term 'bond strength' as applied to reinforced concrete.*

(*b*) *Describe, with the aid of sketches,* TWO *methods of increasing this bond in concrete.*

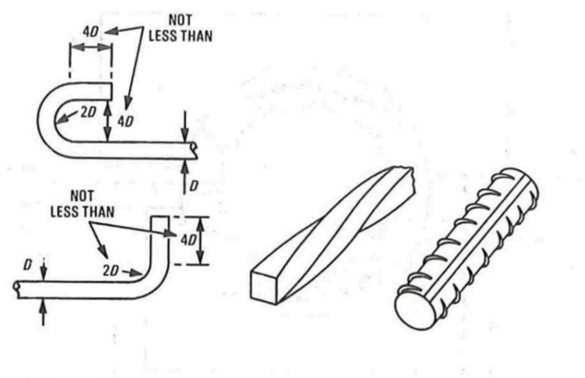
(*c*) *Using a value of 1 MPa for bond strength, calculate the minimum length of embedment of a 10 mm diameter reinforcing rod that would be required to achieve a bond with the concrete. The maximum tensile stress in steel is 140 MPa.*

A10 (*a*) Bond strength in reinforced concrete refers to the magnitude of the adhesion between the concrete and the steel reinforcing bars, and is the bonding force per unit surface area of the reinforcement.

Concrete shrinks when it sets, thereby creating a firm bond between concrete and steel. It is necessary to embed the steel bars in the concrete for a length which provides sufficient adhesion between concrete and steel; otherwise, the steel bars may slip and fail to take up their proportion of the load.

Reinforcement of concrete must be such that the overall bonding force must be at least equal to the permissible tension in the reinforcing bars. The bonding force is the bond strength multiplied by the surface area of the reinforcing bars in contact with the concrete.

(*b*) Adhesion between the steel and concrete can be increased by using either bent bars or bars that have been deformed by twisting or indenting. Hooked bars are shown in sketch (*a*), and 2 methods of deforming bars are shown in sketch (*b*).



(*a*) (*b*)

(*c*) If L is the length of the steel bar (metres), and d is the diameter (metres), the maximum tension in the bar

$$= 140 \times 10^6 \times \left(\frac{d}{2}\right)^2 \pi \text{ newtons.}$$

The bonding force $= \pi dL \times 10^6$ newtons.
Equating the bonding force and the limiting tension in the bar gives

$$\pi dL \times 10^6 = 140 \times 10^6 \left(\frac{d}{2}\right)^2 \pi.$$

$$\therefore \quad L = \frac{140d}{4},$$

$$= \frac{140 \times 10 \times 10^{-3}}{4},$$

$$= 0{\cdot}35 \text{ m} = \underline{350 \text{ mm}}.$$

LINE TRANSMISSION C 1981

Students were expected to answer any 6 questions

Q1 (*a*) *State the following:*

(*i*) *Thévènin's theorem, and*
(*ii*) *superposition theorem.*

(*b*) *Making use of Thévènin's theorem, determine the power dissipated in the 75 Ω load resistor in the network shown in Fig. 1.*

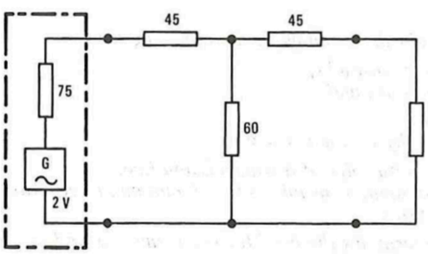


Fig. 1

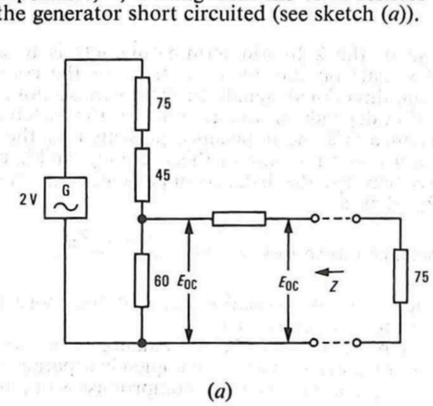
A1 (*a*) (*i*) Thévènin's theorem states that a network can be replaced by a generator of magnitude E in series with an impedance Z, where E is the open circuit voltage of the network, and Z is the impedance looking into the terminals of the network with all generators replaced by impedances equal to their internal impedances.

(*ii*) The superposition theorem states that the current that flows in any network due to any number of applied voltages is the sum of the currents that would flow if each of the voltages were considered separately and with all the generators, except the one under consideration, replaced by impedances equal to their internal impedances.

(*b*) To use Thévènin's theorem to find the current, and hence the power, in the 75 Ω load resistor, it is necessary to determine the following:

(*i*) the open-circuit voltage, E_{oc}, of the network that is connected to the 75 Ω resistor; and

(*ii*) the impedance, Z, looking from the 75 Ω resistor into the network with the generator short circuited (see sketch (*a*)).



(*a*)

Open-circuit voltage, E_{oc}
Since no current flows through the right-hand 45 Ω resistor, under open-circuit conditions E_{oc} is the voltage that exists across the 60 Ω resistor (see sketch (*a*)).

Hence, $\quad E_{oc} = 2 \times \dfrac{60}{75 + 45 + 60} = \dfrac{2}{3}$ V.

Equivalent impedance, Z
Sketch (*b*) shows how the network connected to the 75 Ω resistor is decomposed into a single resistance.

The equivalent impedance, Z, is therefore 85 Ω.

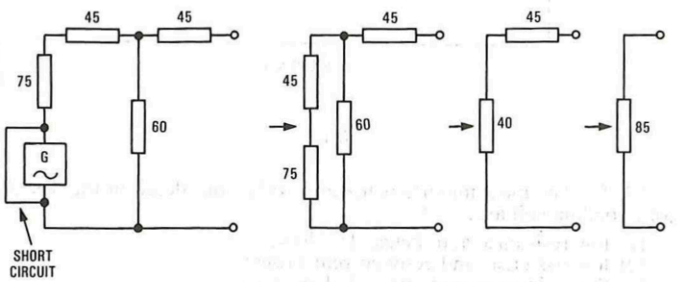
Sketch (*c*) shows the Thévènin equivalent of the network connected to the 75 Ω load resistor.

The current in the circuit, I, is given by

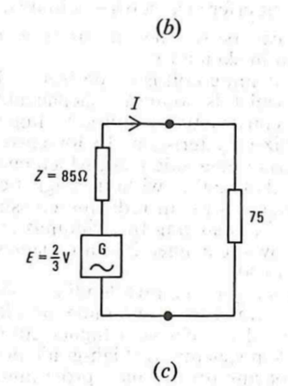
$$I = \frac{2}{3 \times 160} \text{ A.}$$

Therefore the power in the 75 Ω resistor

$$= I^2 \times 75 = \left(\frac{2}{3 \times 160}\right)^2 \times 75 = \underline{0{\cdot}0013 \text{ W}}.$$



(*b*)



(*c*)

Q2 (*a*) *State the principal purpose of loading cable.*

(*b*) *Explain the meaning of the terms*

(*i*) *continuous loading, and*
(*ii*) *lumped loading.*

(*c*) *Using the same axis, sketch the attenuation/frequency characteristics for the following types of audio cable*

(*i*) *unloaded,*
(*ii*) *continuously loaded,*
(*iii*) *lump loaded, using loading of L henries, and*
(*iv*) *lump loaded, using loading of L/2 henries.*

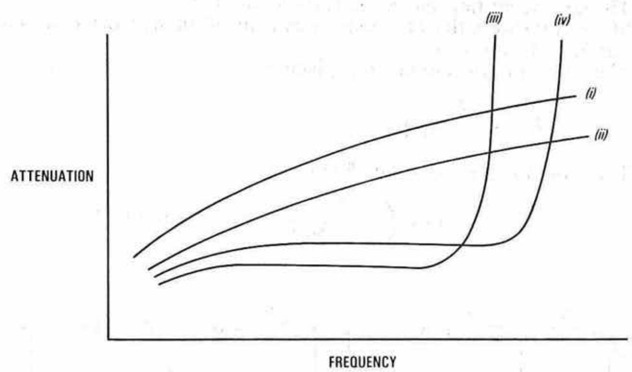
(*d*) (*i*) *Illustrate the construction of a loading coil.*
(*ii*) *What precautions are necessary to minimize crosstalk?*
(*iii*) *State typical loading coil spacings at audio frequencies.*

A2 (*a*) The principal purpose of loading cables is to reduce the attenuation of the cable. At the same time, the attenuation/frequency response is improved (see part (*c*)).

(*b*) (*i*) Loading reduces the attenuation of a cable by increasing the inductance, and hence the impedance of the cable. By virtue of the increased impedance, the current in the cable is reduced, and so the I^2R resistive losses are lowered. Ideally, the increased inductance would be achieved uniformly along the cable. One method of doing this, which is used for submarine cables, is to wrap a ferrous tape around the outer of the cable in a continuous spiral. This is known as *continuous loading*, since the increase in inductance occurs without break along the whole length of the cable.

(*ii*) Continuous loading is expensive, and a cheaper alternative, where a less perfect solution is acceptable, is to achieve the increase in inductance by inserting coils at regular intervals along the cable. This technique is known as *lumped loading*. Under these circumstances, the performance of the cable is different to that when continuous loading is employed. Since the succession of lumped inductances is interspersed with cable capacitances, the overall effect is that of a filter, of which the attenuation rises rapidly after the frequency exceeds a certain value. This value is known as the *cut-off frequency* of the lump-loaded cable.

(*c*) Sketch (*a*) shows the form of the attenuation/frequency characteristics for the cables stated.



(*a*)

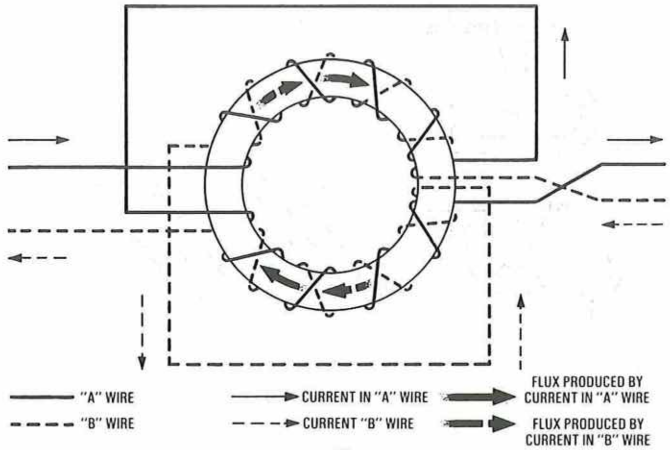
(*d*) (*i*) The most important features to be considered in the design of a loading coil are:

(*1*) low resistance and, hence, low loss;
(*2*) low hysteresis and eddy current losses;
(*3*) the maintenance of circuit balance; and
(*4*) the avoidance of interference between circuits.

These requirements can be satisfied by using a toroidal core with split windings as shown in sketch (*b*).

(*ii*) The core of the loading coil is made from a high permeability material in dust form, which is bound by shellac and compressed into flat rings. This type of construction enables loading coils of small size to be made and minimizes hysteresis and eddy-current losses. It also gives a very small external magnetic field, which enables a number of coils to be stacked closely together without magnetic coupling causing crosstalk. The other main factor in reducing crosstalk is to ensure a high order of accuracy in balancing the windings of the loading coil, and the sketch shows how the connections are made so that the 2 parts of the winding are identical.

(*iii*) The normal spacing of 88 mH loading coils used for audio frequency pairs is 1·83 km. For programme circuits, lighter loading and closer spacing is used to achieve a higher cut-off frequency; for example, 16 mH at 915 m spacing for high-grade programme circuits, and 22 mH at 458 m spacing for ordinary programme circuits.



(*b*)

Q3 (*a*) *With reference to crosstalk, explain the meaning of the following terms*

(*i*) *near-end,*
(*ii*) *far-end,*
(*iii*) *balancing, and*
(*iv*) *transposition.*

(*b*) *Explain how either pair or quad transposition is employed in audio cables, to minimize capacitive imbalance.*

(*c*) *Explain why it is necessary to use balancing networks in multipair carrier cables.*

A3 See A6, Line Transmission C 1980, *Supplement*, Vol. 74, p. 15, April, 1981.

Q4 (*a*) *Explain the meaning of the following terms*

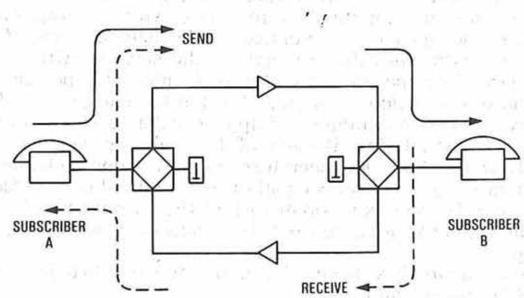
(*i*) *balance return loss,*
(*ii*) *singing point, and*
(*iii*) *echo.*

(*b*) *Explain why it is necessary to*

(*i*) *ensure uniformity of a transmission line.*
(*ii*) *fix maximum transmission and minimum reception levels in a transmission system.*

(*c*) *What determines the need for echo suppression?*

A4 (*a*) (*i*) A 4-wire connection between subscribers A and B is shown in the sketch.



The purpose of the 2 hybrid terminating sets is to separate the bi-directional signals on the 2-wire sections of the connection into separate and uni-directional signals on the 4-wire section. The success of this separation depends on the accuracy of the match between the balance impedance and the impedance presented by the 2-wire line. Balance return-loss is a measure of this accuracy, and is calculated as the return-loss between the balance impedance, Z_B, and the 2-wire impedance, Z_0; that is

$$\text{balance return-loss} = 20 \log_{10}\left|\frac{Z_0 + Z_B}{Z_0 - Z_B}\right|. \qquad \ldots\ldots (1)$$

It can be deduced from equation (1) that the more accurate the balance, the greater the return-loss.

(*ii*) In equation (1), if $Z_0 = Z_B$, the balance return-loss is infinite, and the send and receive signals are completely separate. However, in practice, the balance impedance is a compromise value to accommo-

date a large range of 2-wire impedances, and a perfect match is never attained.

If it is assumed, for example, that subscriber A in the sketch is speaking, then signals pass to subscriber B over the path indicated by the full-line arrows. If there is any imperfection in the match at the receiving-end terminating set, part of the received signal is passed back to subscriber B over the path shown by the dashed line. A similar effect occurs at the terminating set to which subscriber A is connected, so that there exists circulating currents in the 4-wire loop. If the total loss around the loop is not at least 0 dB, the magnitude of these currents increases, and oscillation or *singing* occurs. The singing point is defined as the maximum gain a 2-wire amplifier can be given (without producing singing) when one hybrid terminating set is terminated in a line and its associated balancing network, and the other hybrid terminating set terminated by 600 Ω and a disconnection.

(*iii*) If subscriber A is talking, and the time delay around the circuit is sufficiently long, then the signal passed back to subscriber A, because of the imperfection in the match at the receiving-end terminating set, appears as an echo. This is known as *talker echo*. Similarly, subscriber B hears a delayed signal from subscriber A after the direct signal. This is known as *listener echo*.

(*b*) (*i*) It is necessary to ensure the uniformity of a transmission line to avoid unwanted reflections. Such reflections occur at any electrical discontinuity and affect the characteristic impedance of the line; they can also cause echo effects.

(*ii*) Maximum transmission levels are set to avoid unwanted crosstalk between adjacent circuits and to avoid possible overload of transmission equipment. In multi-channel systems, overload causes cross-modulation between channels; this effect is manifested either as crosstalk into other channels (depending on the cross-modulated frequencies), or as a rise in the noise levels in the system.

It is necessary to set minimum reception levels to ensure that the signal-to-noise ratio is adequate and that the wanted signals are sufficiently high compared with any crosstalk.

(*c*) The subjective effect of talker echo depends on the delay time of the echo as well as the amplitude of the echo. If the delay is very short, the echo is not perceptible as an echo, but sounds like increased sidetone. However, as the delay increases, so does the annoyance value of the echo, and eventually a point is reached where conversation is so interrupted that the affected circuit is not usable. Thus, echo suppressors are required when propagation times are significant; for example, on international circuits, satellite circuits, and long national circuits which can occur in countries such as the USA.

Q5 *Fig. 2 below illustrates the assembly of 12 audio channels into a CCITT group.*

(*a*) *State the functions of* EACH *block shown.*

(*b*) *With respect to a 12-channel group, state the type of*

(*i*) *channel filter,*
(*ii*) *channel modulation, and*
(*iii*) *channel modulator.*

(*c*) *Explain why 12 audio channels are assembled in the frequency range 60–108 kHz rather than 0·3–48 kHz.*

(*d*) *Sketch a typical loss/frequency characteristic for the band-pass filter in Fig. 2. Clearly scale the axis for* ONE *of the 12 channels.*

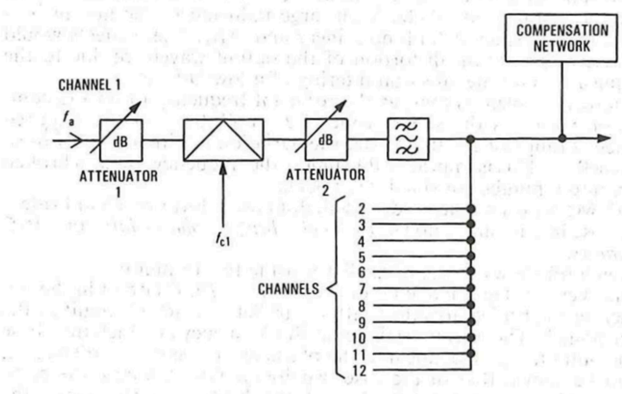


Fig. 2

A5 (*a*) Attenuator 1 is used to adjust the incoming signal level so that the modulator is not overloaded. The modulator translates the incoming speech signal, which is in the range 300–3400 Hz, to one of the channels in the range 60–108 kHz. In the case shown, the carrier frequency for channel 1 is 108 kHz. Attenuator 2 is provided so that the levels from all 12 channels can be adjusted to be equal. The modulator output contains both upper and lower sidebands. However, only the lower sideband is used, so that a highly accurate band-pass filter is required to select the lower sideband and reject the upper sideband.

Channels 1 and 12 have only one filter with an adjacent frequency response, whereas channels 2–11 have two. Therefore, a compensating network is required to correctly load the filters and, hence, provide the required response.

(*b*) (*i*) Because of the demanding attenuation/frequency requirements for each channel filter, a crystal filter is used.

(*ii*) Amplitude modulation is used to create lower and upper sidebands.

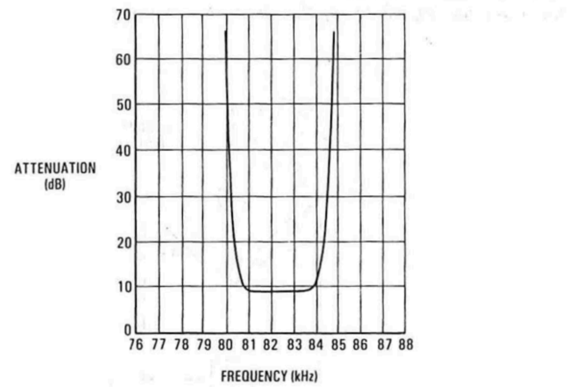
(*iii*) A Cowan (ring) modulator is used; the main virtue of this modulator is its low level of carrier leakage.

(*c*) If a low-frequency range such as 0·3–48 kHz were used, 2 problems would arise:

(*i*) Harmonics from the modulation process on the lower channels would fall in the upper channels, even after filtering; this would give rise to multiple crosstalk.

(*ii*) At low frequencies it would be extremely difficult to achieve the required filter responses.

(*d*) The sketch shows the response of a filter suitable for channel 7.



Q6 *The primary coefficients of a 1 km transmission line are $R = 35\ \Omega$, $C = 0{\cdot}05\ \mu F$, $L = 1$ mH and $G = 100\ \mu S$.*

For $\omega = 10\,000$ rad/s calculate

(*a*) *the characteristic impedance, and*
(*b*) *the attenuation in decibels.*

A6 (*a*) For a uniform transmission line, the characteristic impedance, Z_0, is given by the expression

$$Z_0 = \sqrt{\left(\frac{R + \mathrm{j}\omega L}{G + \mathrm{j}\omega C}\right)} \text{ ohms,}$$

where R is the loop resistance (ohms/kilometre), L is the loop inductance (henrys/kilometre), G is the loop leakance (siemens/kilometre), C is the capacitance (farads/kilometre) and ω is the angular frequency (radians/second).

Substituting the given values,

$$R + \mathrm{j}\omega L = 35 + \mathrm{j}10 = 36{\cdot}40 \angle 15{\cdot}9°, \text{ and}$$

$$G + \mathrm{j}\omega C = (1 + \mathrm{j}5) \times 10^{-4} = 5{\cdot}099 \times 10^{-4} \angle 78{\cdot}7°.$$

$$\therefore \quad |Z_0| = \sqrt{\left(\frac{36{\cdot}4}{5{\cdot}099 \times 10^{-4}}\right)} = 267{\cdot}2\ \Omega, \text{ and}$$

$$\arg Z_0 = \frac{15{\cdot}9° - 78{\cdot}7°}{2} = -31{\cdot}4°.$$

$$\therefore \quad Z_0 = \underline{267{\cdot}2 \angle -31{\cdot}4°\ \Omega.}$$

(*b*) The propagation coefficient γ, of a uniform transmission line, is given by the expression

$$\gamma = \sqrt{\{(R + \mathrm{j}\omega L)(G + \mathrm{j}\omega C)\}} = \alpha + \mathrm{j}\beta,$$

where α is the attenuation coefficient (nepers/kilometre), and β is the phase change coefficient (radians/km).

Thus, $\gamma = \sqrt{(36 \cdot 40 \times 5 \cdot 099 \times 10^{-4})} \angle \left(\frac{15 \cdot 9° + 78 \cdot 7°}{2}\right)$,

$= 0 \cdot 136 \angle 47 \cdot 3°$.

The attenuation coefficient, α is the real part of γ.

$\therefore \quad \alpha = 0 \cdot 136 \cos 47 \cdot 3 = 0 \cdot 092$ Np/km.

Therefore, the attenuation of the transmission line is

$8 \cdot 686 \times 0 \cdot 092 = \underline{0 \cdot 80 \text{ dB/km}}$.

Q7 (a) The performance of a telephone instrument is to be assessed. State the frequency range in an audio channel that mainly influences

(i) volume, and
(ii) articulation.

(b) In the assessment of a telephone instrument, explain the meaning and merit of subjective and objective tests.

(c) With the aid of a diagram, explain how the maximum tolerable losses are apportioned in a trunk and junction transmission network. In the plan described, indicate the exchanges which employ 2-wire switching.

Q8 (a) Explain the meaning of the following terms

(i) through level measurement, and
(ii) terminated measurement.

(b) Fig. 3 illustrates a bridge suitable for the measurement of the line impedance of an audio cable. In terms of the bridge components state the balance conditions and hence derive an expression, in polar form, for the impedance of the circuit under test.

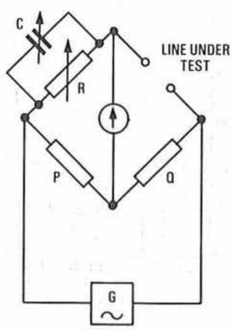


Fig. 3

A8 (*a*) An instrument used for the measurement of voltage levels has a particular input impedance, and this affects the circuit or equipment to which it is connected while the measurement is being made. One approach to this problem is to make the impedance of the level measuring set (LMS) sufficiently high so that the loading effect of the LMS does not significantly affect the true voltage level.

Another solution is to define the impedance of the LMS accurately as some appropriate value, so that the effect of the LMS is accurately known. It is convenient to set the impedance equal to the nominal impedance of the circuit or equipment being measured; that is, the LMS is designed to be matched.

Where the input impedance of the LMS is large compared with the circuit impedance, the LMS can be bridged across the circuit being measured. An appropriate "rule of thumb" requirement is that the LMS should have an input impedance at least ten times that of the circuit being measured. For measurements on circuits having nominal impedances of 600 Ω, an input impedance of at least 6000 Ω is required; most LMSs exceed this figure. This type of measurement is known as a *through level measurement*.

There are many circumstances where a level measurement which involves breaking a circuit has to be made; this removes the matching effect of the equipment that would normally be in place had the break not been made. In this case, the LMS should provide an impedance which matches that of the circuit under investigation. This is known as a *terminated measurement*.

Practical audio LMSs are designed with very-high input impedances, thus satisfying the requirements of through level measurements. To enable terminated measurements to be made. LMSs have a switched facility for connecting an accurate 600 Ω resistor across the input terminals to provide a good match for 600 Ω audio equipment.

(*b*) Denoting the impedance of the line under test as X ohms, and the impedance of the parallel capacitor C and resistor R as Z_{RC} ohms, the bridge is balanced when the condition

$$\frac{P}{Q} = \frac{Z_{RC}}{X} \text{ is satisfied.}$$

Now, $\dfrac{1}{Z_{RC}} = \dfrac{1}{R} + j\omega C$.

$\therefore \quad Z_{RC} = \dfrac{R}{1 + j\omega CR}$.

Since, $X = \dfrac{Z_{RC}Q}{P}$,

then, substituting for Z_{RC},

$$X = \frac{RQ}{(1 + j\omega CR)P}.$$

Multiplying the top and bottom of the above equation by $(1 - j\omega CR)$,

$$X = \frac{RQ(1 - j\omega CR)}{P(1 + \omega^2C^2R^2)}.$$

$$\therefore \quad |X| = \frac{RQ\sqrt{(1 + \omega^2C^2R^2)}}{P(1 + \omega^2C^2R^2)} = \underline{\frac{RQ}{P\sqrt{(1 + \omega^2C^2R^2)}}},$$

and, $\arg X = \underline{\tan^{-1}(-\omega CR)}$.

Q9 (a) In connection with line transmission equipment, explain the meaning of the following terms

(i) localized power unit, and
(ii) centralized power plant.

(b) Explain how a low-voltage centralized power supply may be provided in a repeater station. Include provision for mains failure.

(c) State TWO *advantages and* TWO *disadvantages of centralized power supplies.*

Q10 (a) A variable oscillator is required to operate over the range 50–10 000 Hz.

(i) State TWO *features that would be desirable for such an oscillator.*
(ii) Explain why a simple LC oscillator is not suitable.
(iii) Describe briefly, how a suitable solution could be obtained by using EITHER *a heterodyne* OR *a phase-shift technique.*

(b) An unknown frequency is to be compared with a variable reference frequency. Describe how this comparison could be achieved with the aid of a cathode-ray oscilloscope (CRO). Include an example of a possible CRO display.

A10 (*a*) (*i*) Although the technical requirements of such an oscillator depend on the particular use for which it is required, 2 general requirements are that

(*1*) the output level should not vary significantly with frequency, and
(*2*) the output signal should be reasonably free of unwanted harmonics and noise.

(*ii*) In principle, the LC oscillators used at radio frequencies could be scaled for use at audio frequencies. However, at audio frequencies, large values of capacitance and inductance are necessary; for example, with a capacitance of 1 μF, an inductance of 10 H is required for the circuit to resonate at 50 Hz. Such large inductances require an iron core material, which is both non-linear and lossy. These effects would give rise to significant distortion of the output waveform due to the non-linearity and the affect on filtering of a low Q-factor.

Another problem is that, as the resonant frequency of an LC combination varies as the square root of L or C, to meet the required frequency range of 50–10 000 Hz, the variation in either L or C must be 40 000 : 1. This is impracticable unless the frequency range is broken down into a number of smaller segments.

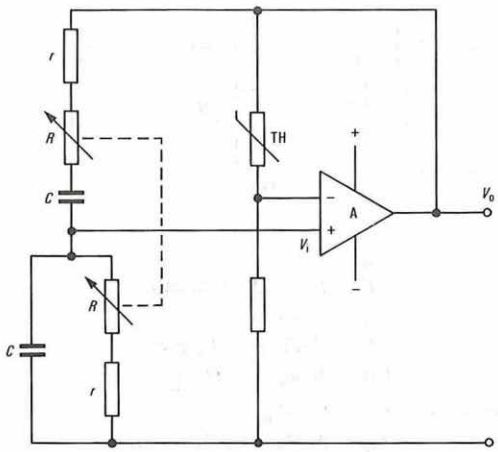
(*iii*) Most present-day audio oscillators use a form of Wein bridge; these oscillators are known as *Wein bridge, phase-shift*, or *AGC oscillators*.

Sketch (*a*) shows a simple oscillator using this technique.

The Wein bridge is made up of a series ($r + R$), C circuit in the top branch of the bridge, together with a parallel ($r + R$), C circuit in the lower branch. The circuit oscillates at the frequency at which the phase of the output, V_0, is identical to the phase of the feedback voltage, V_i. It can be shown that in the case usually employed, where the component values in the 2 branches of the bridge are the same, the frequency of oscillation, f, is given by

$$f = \frac{1}{2\pi(R + r)C}.$$

The range of variation is given by the ratio $(R + r)/r$, which can be

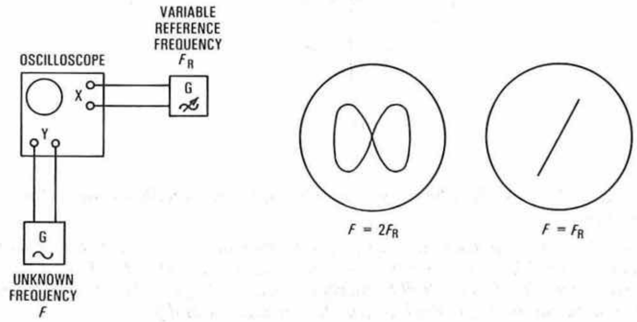


(*a*)

made considerable. These 2 relationships demonstrate the ease with which the shortcomings of an LC oscillator are overcome: the frequency is a linear function of the variable resistance and the required range is simply chosen. Although the attenuation of the bridge is low ($V_i = V_0/3$), thus placing no great demands on amplifier A, amplitude stabilization is always employed, and a popular method is to use a thermistor (TH). If the output level tends to rise, more current passes through the thermistor, thus heating it and causing its resistance to decrease. This decrease in resistance applies more negative feedback via the inverting input of amplifier A, and so counteracts the rise in output level. Such stabilization is necessary because the matching of r, R, and C in the 2 branches of the bridge is imperfect, and a real gain in excess of 3, which varies slightly with frequency, is required.

(*b*) An unknown frequency, F, can be compared with a known variable reference frequency, F_R, by connecting the 2 signals to an oscilloscope in the way shown in sketch (*b*).

Sketch (*c*) shows the type of waveform obtained on the oscilloscope display before any adjustment to the variable reference oscillator has been made. The figure described by the oscilloscope trace is known as a *Lissajou figure*. Initially, there are many more loops than the 2 shown for the particular case where $F = 2F_R$, and the loops rotate rapidly depending on the relative frequencies F and F_R. By adjusting F_R, provided that it is possible to achieve $F_R = F$ by such adjustment, a circle, stationary ellipse or straight line is obtained. Sketch (*d*) shows the case where F_R and F are equal in frequency and exactly in phase; the slope of the line is dependant upon the relative amplitudes of the 2 oscillators. In practice, small differences between the X and Y amplifiers in the oscilloscope, particularly at higher audio frequencies, cause the line to become slightly looped at its extremities.



(*b*) (*c*) (*d*)

TELECOMMUNICATION PRINCIPLES C 1981

Students were expected to answer any 6 questions

Q1 (*a*) *State the superposition theorem.*

(*b*) *Fig. 1 shows a 15 m length of loss-free 75 Ω transmission line which is fed from both ends by sources of 75 Ω internal resistance. The sources have the same frequency of 20 MHz and are in phase. The velocity of propagation on the line is 2×10^8 m/s.*

Determine

(*i*) *the wavelength on the line,*

(*ii*) *the current magnitudes at each end of the line when $V_2 = 0$,*

(*iii*) *the current magnitudes at each end of the line when $V_2 = 5$ V, and*

(*iv*) *the current at the midpoint of the line when $V_2 = 5$ V.*

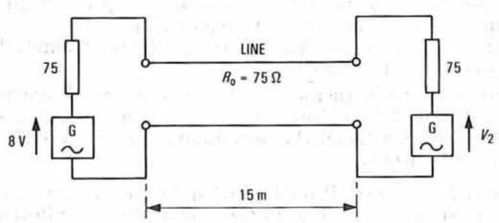


Fig. 1

A1 (*a*) The superposition theorem states that the effect of a number of sources acting independently may be determined by calculating the effect of each separately and summing the effects.

(*b*) (*i*) The wavelength of the line is determined from the equation $V = f\lambda$, where V is the velocity of propagation in metres/second, f is the frequency in hertz and λ is the wavelength in metres.

Thus, $$\lambda = \frac{2 \times 10^8}{20 \times 10^6} = \underline{10 \text{ m.}}$$

(*ii*) For each source, the line can be regarded as a perfectly terminated transmission line because the generator impedances are both 75 Ω, which is also the characteristic impedance of the line.

For $V_2 = 0$, it is only necessary to consider the left-hand source. The input current, I_{in}, is given by the expression

$$I_{in} = \frac{8}{75 + 75} = \underline{53 \cdot 3 \text{ mA.}}$$

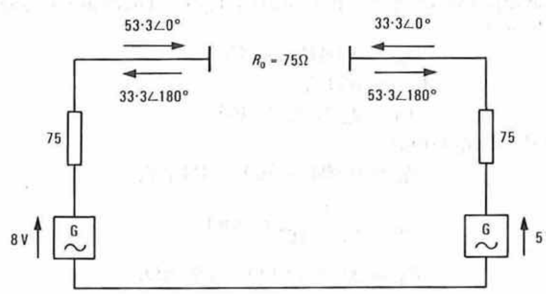
Since the line is loss free, the output current is the same as the input current.

(*iii*) When V_2 is 5 V, the current flowing in the line due to V_2 is

$$\frac{5}{75 + 75} = 33 \cdot 3 \text{ mA.}$$

Since the line is 1·5 wavelengths long, each current undergoes a 540° phase shift from its respective generator and load.

Sketch (*a*) shows that the currents are additive at the ends of the line. Thus, the total currents are $\underline{86 \cdot 6 \text{ mA.}}$

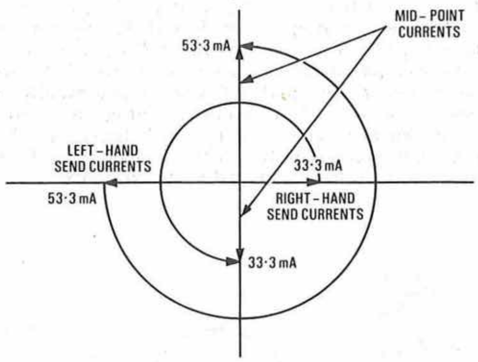


(*a*)

(*iv*) At the centre of the line, each current has undergone a phase change of 270° relative to the sending phase. The current is then the sum of

$$53 \cdot 3 \angle 270° + 33 \cdot 3 \angle (180° + 270°).$$

This has a magnitude of 20 mA. This is illustrated in sketch (*b*).



(*b*)

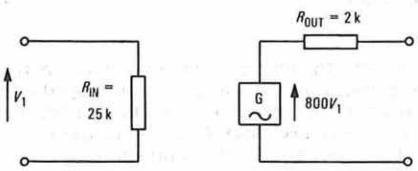
Q2 (*a*) *Discuss the effects of applying negative feedback to a 2-port amplifier.*

(*b*) *A 2-port amplifier has an internal resistance of 25 kΩ, an output resistance of 2 kΩ and an open-circuit voltage gain of 800. A feedback network, which takes negligible current, provides 4% negative feedback in series with the input. Calculate for the feedback amplifier*

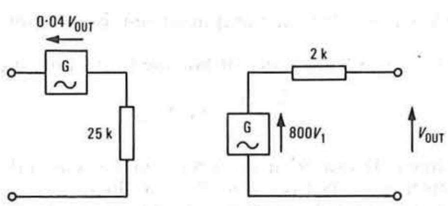
(*i*) *the input resistance,*
(*ii*) *the output resistance,*
(*iii*) *the voltage gain, and*
(*iv*) *the percentage change in gain, if the gain of the basic amplifier falls by 20%, from 800 to 640.*

A2 (*a*) See A3(*a*) Telecommunication Principles C 1980, *Supplement*, Vol. 73, p. 83, Jan. 1981.

(*b*) Sketch (*a*) represents the equivalent circuit of the 2-port amplifier before feedback is applied. Sketch (*b*) represents the equivalent circuit when feedback is applied.



(*a*)



(*b*)

(*i*) The input resistance is the ratio of V_{in}/I_{in}. There are 3 equations for the network:

$$V_{in} = 0 \cdot 04 V_{out} + V_1.$$
$$V_{out} = 800 V_1.$$
$$V_1 = I_{in} \times 25 \times 10^3.$$

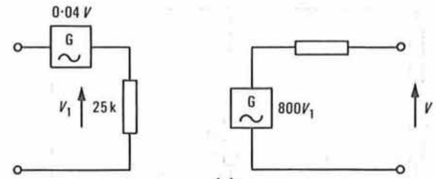
From these equations

$$V_{in} = (0 \cdot 04 \times 800 + 1) V_1 \text{ V},$$

$$I_{in} = \frac{V_1}{25 \times 10^3} \text{ A, and}$$

$$R_{in} = 33 \times 25 \text{ k}\Omega = 825 \text{ k}\Omega.$$

(*ii*) The output resistance can be found by applying a voltage at the output and calculating the current that flows, as shown in sketch (*c*).



(*c*)

$$R_{out} = V/I.$$
$$V = I \times 2000 + 800 V_1.$$
$$V_1 = -0 \cdot 04 V.$$

Thus,

$$V = 2000I - 32V, \text{ and}$$
$$V/I = 2000/33 = 60 \ \Omega.$$

(*iii*) The voltage gain is V_{out}/V_{in}.

$$V_{in} = 0 \cdot 04 V_{out} + V_{out}/800,$$
$$= V_{out}(0 \cdot 04 + 0 \cdot 00125).$$
$$V_{out}/V_{in} = 24 \cdot 2.$$

(*iv*) When the open loop gain falls by 20%, the equation used in part (*iii*) becomes:

$$V_{in} = V_{out}(0 \cdot 04 + 1/640), \text{ and}$$
$$V_{out}/V_{in} = 24.$$

Therefore, the percentage fall in voltage gain is

$$\frac{0 \cdot 2}{24 \cdot 2} \times 100 = 0 \cdot 83\%.$$

Q3 (*a*) *What are the basic differences between frequency-division multiplexing (FDM) and time-division multiplexing (TDM)?*

(*b*) *A TDM system is designed to transmit ten commercial speech channels. Giving reasons at EACH step, estimate*

(*i*) *the total number of pulses per second, and*
(*ii*) *the duration of EACH pulse.*

(*c*) *Ten speech channels are to be multiplexed using FDM. Suggest suitable carrier frequencies for the channels and hence estimate the bandwidth of the complete system.*

A3 (*a*) Multiplexing is the term used to describe the process of sharing some property of a transmission medium. A number of signals can then share the transmission medium and be transmitted independently.

In time-division multiplexing (TDM) each signal has access to the transmission medium for only part of the available time, the remainder of the time being occupied by the signals of other channels. In frequency-division multiplexing (FDM), each signal occupies only part of the available bandwidth, the baseband signal being translated by modulating a carrier frequency.

This means that TDM signals cannot be coincident in time and FDM signals cannot be coincident in frequency.

(*b*) (*i*) A commercial speech channel occupies a frequency spectrum of 300–3400 Hz. After an allowance for imperfections in the filters employed to limit the bandwidth of the signal has been made, the bandwidth is taken to be 4 kHz. In a TDM system it is necessary to sample the signal at a rate which is at least twice the highest frequency to be transmitted; thus, in order to transmit a commercial speech channel sampling must take place at least at 8 kHz.

Each channel thus requires 8000 pulses/s; with 10 channels the total number of pulses/second is 80 000.

(*ii*) In order to avoid distortion of the transmitted signals there must be no overlap of the pulses. Therefore, the minimum duration of each pulse is 1/80 000 s. Thus, the maximum pulse width is 12·5 μs; it would typically be 10 μs.

(*c*) For an FDM system (if single-sideband transmission is assumed) a single channel would require 4 kHz, again after an allowance for imperfections in the filters used for channel separation has been made. Thus, 10 channels would require a bandwidth of 40 kHz. The carrier frequencies could be multiples of 4 kHz, with the first channel being transmitted as a base-band signal. Therefore, suitable carrier frequencies would be 0, 4, 8, . . . 36 kHz.

Q4 (*a*) *Explain how a Norton equivalent circuit can be derived from a Thévènin equivalent circuit.*

(*b*) *Obtain Thévènin and Norton equivalent circuits for terminals A and B in Fig. 2. Hence, or otherwise, calculate the magnitude of the current in a 500 Ω resistor connected across A and B.*

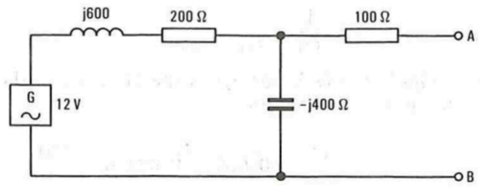


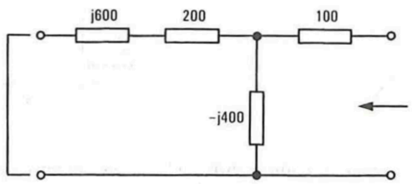
Fig. 2

A4 (*a*) The equivalence of Norton and Thévènin circuits is obtained if the open-circuit voltage and short-circuit current obtained in both cases is the same.

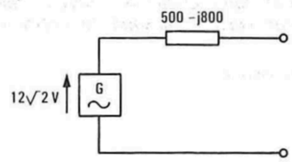
(*b*) The open-circuit voltage for the network is given by the expression

$$12 \times \left(\frac{-j400}{-j400 + 200 + j600}\right) = \frac{-j48}{2(1+j)} = -j12(1 - j).$$

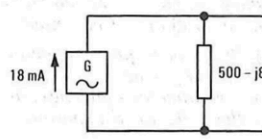
For the purpose of calculation the phase of the source can be adjusted so that the open-circuit voltage is $\sqrt{2} \times 12$ V. The Thévènin impedance is calculated from the circuit shown in sketch (*a*).



(*a*)



(*b*)



(*c*)

$$Z_T = 100 + \frac{-j400(200 + j600)}{-j400 + 200 + j600},$$
$$= 100 - j(200 + j600)(1 - j),$$
$$= 100 + (200 + j600)(-1 - j),$$
$$= 100 + (-200 - j600 - j200 + 600),$$
$$= 500 - j800.$$

The Thévènin equivalent network is shown in sketch (*b*).

The Norton equivalent circuit has the same impedance and the short-circuit current is

$$\frac{12 \times \sqrt{2}}{500 - j800}.$$

In magnitude, this current is $\dfrac{12\sqrt{2}}{\sqrt{(500^2 + 800^2)}} = 18$ mA.

Again, for the purpose of calculation the phase angle can be ignored. The circuit is shown in sketch (*c*).

The magnitude of the current in the 500 Ω resistor connected across terminals A and B is

$$12\sqrt{2}/\sqrt{(1000^2 + 800^2)} = \underline{13 \cdot 3 \text{ mA.}}$$

Q5 (*a*) *A sinusoidal carrier with a peak voltage of 15 V and a frequency of 20 kHz is amplitude modulated to a depth of 35% by a 2 kHz sinusoidal signal.*

Write down an equation which represents the wave and calculate

(*i*) *the amplitude and frequency of* EACH *side frequency component, and*

(*ii*) *the power developed, if the modulated wave is applied to a 75 Ω resistance.*

(*b*) *The diagram in Fig. 3 shows an amplitude modulator which is monitored by an oscilloscope. The output of the modulator being connected to the "Y" deflection system and the modulating signal to the "X" deflection system. The Y and X sensitivities are suitably adjusted and the display is an illuminated trapezium. Sketch the form of the display and explain its shape. If the long vertical side of the display has a length of 5 cm and the short vertical side is 3 cm, calculate the modulation depth of the wave.*

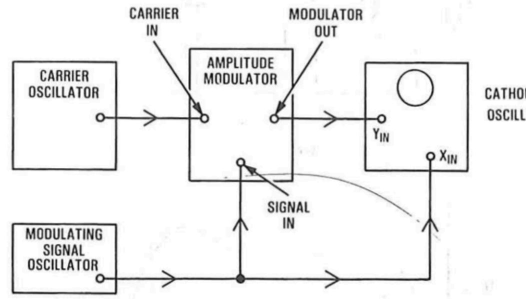


Fig. 3

A5 (*a*) An equation which represents the amplitude-modulated waveform is

$$V = 15(1 + 0 \cdot 35 \sin 2\pi \times 2 \times 10^3 t) \sin (2\pi \times 20 \times 10^3 t).$$

(*i*) The frequencies of the side frequencies are (20 ± 2) kHz; that is, 22 kHz and 18 kHz.

Their magnitudes are

$$\frac{15 \times 0 \cdot 35}{2} \times \frac{1}{\sqrt{2}} = \underline{1 \cdot 86 \text{ V RMS.}}$$

(*ii*) The power in a 75 Ω resistance to which the modulated wave is applied is

$$\frac{1}{75} \times \left(\frac{15}{\sqrt{2}}\right)^2 + 2\left(\frac{1 \cdot 86^2}{75}\right) = \underline{1 \cdot 6 \text{ W.}}$$

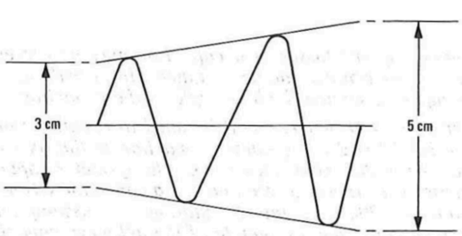
(*b*) The shape of the display is shown in the sketch. The envelope appears as a straight line because the X-input is the modulating waveform, instead of a linear ramp, which is more usual in the use of an oscilloscope. The zero crossings are spaced at different intervals because of the changing slope of the deflection waveforms. The depth of modulation is calculated from the expression

$$\frac{1 + k}{1 - k},$$

where k is the depth of modulation.

$$\therefore \quad 3 + 3k = 5 - 5k.$$

$$\therefore \quad k = \frac{5 - 3}{8} = 0 \cdot 25 = \underline{25\%.}$$



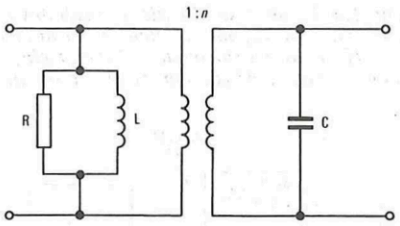
Q6 (*a*) *Sketch an equivalent circuit for an iron-cored transformer and explain the significance of* EACH *element in that circuit.*

(*b*) *Sketch the frequency responses of a typical iron-cored audio transformer and explain the shape of the response curve.*

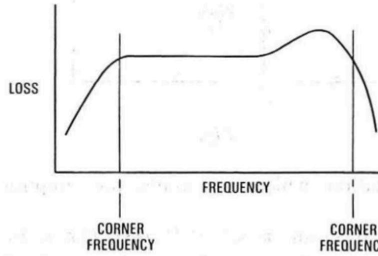
A6 (*a*) The equivalent circuit of an iron-cored transformer is shown in sketch (*a*).

The resistance R represents the total losses (that is, copper and iron losses) of the transformer; L represents the shunt inductance and C is the total capacitance of the windings represented, in this case, on the secondary side of the transformer. The transformer ratio is $1:n$, the ratio of the number of turns on the primary to the number on the secondary.

(*b*) A typical response curve is shown in sketch (*b*). The reduction in response at low and high frequencies is because of the shunt impedance



(*a*)



(*b*)

of the inductance and capacitance respectively. The "corner frequencies" depend on the load resistance at which the transformer is operated. The rise in the response at high frequencies is because of the resonance of the inductance and capacitance.

Q7 (*a*) *State and justify the basic bandwidths of the following communications signals*

(*i*) *speech,*
(*ii*) *music, and*
(*iii*) *a 625-line, black and white television signal with a frame frequency of 25 frames per second and an aspect ratio of 4:3.*

(*b*) *Explain, with reference to the results in part (a), why amplitude or frequency modulation are both practicable for speech or music but television signals are unlikely to be broadcast using frequency modulation.*

A7 (*a*) See A10, Telecommunications Principles C 1975, *Supplement*, Vol. 69, p. 59, Oct. 1976.

(*b*) The bandwidth required for baseband television transmission is in the order of 6 MHz, while speech and music occupy bands of 4 kHz and 20 kHz respectively. The process of amplitude modulation retains this requirement of bandwidth if single-sideband transmission is used. However, frequency modulation requires, in general, many times the original bandwidth. Applied to television, the bandwidth could only be realized at carrier frequencies outside the range of conventional circuit techniques used in receivers.

Q8 (*a*) *Explain why the losses in a capacitor may be represented by either a series resistance or a parallel resistance. How are these resistances related to the capacitance and the loss angle of the capacitor?*

(*b*) *In a test using a Q-meter, a coil is tuned to resonance at 3 MHz. The Q reading is 210 and the Q-meter capacitor setting is 140 pF. An unknown capacitor is then connected across the Q-meter capacitor. The Q-meter capacitor is re-tuned to resonance at a capacitor setting of 90 pF and a Q-reading of 200 is obtained. Stating any assumptions made, calculate the capacitance and loss-angle of the unknown capacitor.*

A8 (*a*) The losses of a capacitor result in a phase angle between the current and voltage which is slightly less than 90°. This can be accounted for by either

(*i*) 2 components of current, one of which is in phase with the applied voltage, or

(*ii*) 2 components of voltage, one of which is in phase with the capacitor current.

These 2 possibilities correspond to a resistance in parallel with the capacitor or a resistance in series with the capacitor.

The sketch represents these 2 cases with their appropriate phasor diagrams.

The phase angle (δ) is approximately $r/\omega C$ or $\omega C/R$.

(*b*) The capacitance of the unknown capacitor is the difference in the capacitor settings of the Q-meter; that is, 50 pF. In this case the assumption is made that the capacitance is in parallel with the internal capacitance of the Q-meter.

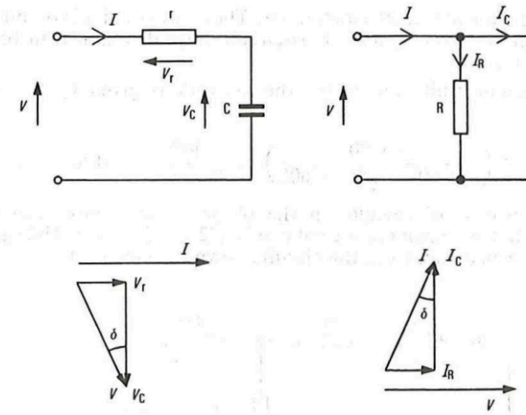
The Q-factor of the capacitor is obtained from the relationship

$$\frac{1}{Q_I} = \frac{1}{Q_L} + \frac{1}{Q_C},$$

where Q_I is the indicated Q-factor, Q_L is the Q-factor of the coil and Q_C is the Q-factor of the capacitor.

$$\therefore \quad Q_C = \frac{1}{0 \cdot 005 - 0 \cdot 00476} = 420.$$

$$\text{The loss angle} = \frac{1}{Q_C} = \frac{1}{420} = 2 \cdot 4 \times 10^{-3} \text{ rad.}$$



Q9 (*a*) *Give* TWO *significant reasons why transformer-coupled loads are often preferred to direct-coupled loads in class-A power amplifiers.*

(*b*) *A common-emitter power amplifier operates from a 15 V power supply. The collector is in series with the primary winding of a 5:1 step-down transformer which has a 3 Ω load connected across the secondary winding. The collector current varies sinusoidally between 40 mA and 400 mA. Determine*

(*i*) *the peak-to-peak collector voltage swing,*
(*ii*) *the output power,*
(*iii*) *the collector efficiency, and*
(*iv*) *the collector dissipation.*

A9 (*a*) The load presented to a power amplifier is frequently different from the optimum load for that amplifier from the point of view of distortion or maximum available power. Some form of matching is therefore required, and this is most easily achieved by using a transformer.

In addition to these factors, power dissipation is minimized by using transformer coupling.

(*b*) (*i*) The peak-to-peak collector voltage swing is equal to $(360 \times 10^{-3} \times 3 \times 25) = \underline{27\text{ V}}$.

(*ii*) The output power is

$$\frac{1}{75} \times \left(\frac{27}{2\sqrt{2}}\right)^2 = \underline{1 \cdot 22\text{ W}}.$$

(*iii*) Collector efficiency is the ratio of the output power to the DC input power, which equals

$$\frac{1 \cdot 22}{15 \times \dfrac{220}{1000}} = \underline{37\%}.$$

(*iv*) The collector dissipation is the difference between the DC input power and the output power.

$$\text{Therefore, dissipation} = 15 \times \frac{220}{1000} - 1 \cdot 22,$$

$$= 3 \cdot 3 - 1 \cdot 22 = \underline{2 \cdot 08\text{ W}}.$$

Q10 (*a*) *In connection with an amplifier, explain the importance of*

(*i*) *input impedance,*
(*ii*) *output impedance, and*
(*iii*) *voltage gain.*

(*b*) *An amplifier is required to have the following specification.*
Input impedance . . . . at least 1 MΩ,
Output impedance . . . . no greater than 2 kΩ,
Voltage gain . . . . 25.
Suggest how this specification could be realized and provide a typical circuit diagram for the amplifier.

Students were expected to answer any 6 questions

Q1 (*a*) *Explain fully why reflection from a narrow vertical metal structure depends on the plane of polarization of the incident wave.*

(*b*) *The total frequency band of a multi-channel communication link is divided into 16 channels. Adjacent channels are allocated vertical and horizontal polarization alternately. What advantage results from this arrangement?*

(*c*) *Describe briefly how the dielectric properties of the troposphere may influence the path of an electromagnetic wave.*

Q2 (*a*) *For a low-loss coaxial cable, state, with reasons, whether an increase in frequency from 100 MHz to 200 MHz will result in a change in*

(*i*) *the characteristic frequency, and*
(*ii*) *the attenuation*
of the cable.

(*b*) *A low-loss coaxial cable, of characteristic impedance 90 Ω, is terminated in a resistive load of 180 Ω. The input impedance of the cable is 45∠0° Ω. Determine the input impedance when the load is replaced by*

(*i*) *a short circuit, and*
(*ii*) *a 75 Ω resistor.*

A2 (*a*) The characteristic impedance, Z_0, of a transmission line is given by the relation

$$Z_0 = \sqrt{\left(\frac{R + j\omega L}{G + j\omega C}\right)},$$

where R is the resistance/unit length, L is the inductance/unit length, C is the capacitance/unit length, G is the conductance/unit length, and ω is 2π times the frequency. For a low-loss coaxial cable, it is possible to state that $\omega L \gg R$, and $\omega C \gg G$ at radio frequencies between 100 and 200 MHz. Therefore, the characteristic impedance of the cable simplifies to

$$Z_0 = \sqrt{\left(\frac{L}{C}\right)}.$$

L and C are parameters that are related to the geometrical dimensions of the cable, and, therefore, changing the frequency of operation of the cable from 100 to 200 MHz has no effect on the characteristic impedance of the cable.

The attenuation constant, α, of a radio-frequency transmission line, where the frequency is high enough so that the previously stated conditions $\omega L \gg R$ and $\omega C \gg G$ hold, is given by the real part of the propagation constant of the line. This relationship is

$$\alpha = \frac{R}{2Z_0} + \frac{GZ_0}{2} \text{ nepers/metre.}$$

R is proportional to the square root of the frequency because of the skin effect. For low-loss coaxial cables G is usually negligible and the above expression reduces to

$$\alpha = \frac{R}{2Z_0} \text{ nepers/metre,}$$

which is proportional to the square root of the frequency.

Therefore, if the operating frequency of the coaxial cable is raised from 100 to 200 MHz, the attenuation increases $\sqrt{2}$ times.

(*b*) The input impedance, Z_{in}, of a length of low-loss transmission line is given by

$$Z_{in} = Z_0 \left\{\frac{(R_L/Z_0)\cos\beta l + j\sin\beta l}{\cos\beta l + j(R_L/Z_0)\sin\beta l}\right\}. \quad \ldots\ldots (1)$$

where R_L is the resistance of the load, β is $2\pi/\lambda$, λ is the wavelength, and l is the length of the transmission line.

For the example given, $Z_{in} = 45\angle 0°$ Ω, $Z_0 = 90$ Ω, and $R_L = 180$ Ω; that is,

$$45 + j0 = 90\left(\frac{2\cos\beta l + j\sin\beta l}{\cos\beta l + j2\sin\beta l}\right).$$

$$\therefore \quad 0\cdot5 + j0 = \left(\frac{2\cos\beta l + j\sin\beta l}{\cos\beta l + j2\sin\beta l}\right) \times \left(\frac{\cos\beta l - j2\sin\beta l}{\cos\beta l - j2\sin\beta l}\right).$$

Equating real parts,

$$0\cdot5 = \frac{2\sin^2\beta l + 2\cos^2\beta l}{4\sin^2\beta l + \cos^2\beta l}.$$

$$\therefore \quad 2\sin^2\beta l + 0\cdot5\cos^2\beta l = 2\sin^2\beta l + 2\cos^2\beta l.$$

$$\therefore \quad \cos\beta l = 0.$$

$$\therefore \quad \beta l = n(\pi/2), \text{ where } n = 1, 3, 5 \ldots \ldots \text{ odd.}$$

$$\therefore \quad l = n\lambda/4.$$

Substituting this result into equation (1),

$$Z_{in} = \frac{Z_0^2}{R_L}.$$

Therefore, if $R_L = 0$ Ω, $Z_{in} = \underline{\infty\ \Omega.}$

(*ii*) When $R_L = 75$ Ω, $Z_{in} = 90 \times 90/75$ Ω, $= \underline{108\ \Omega.}$

Q3 (*a*) (*i*) *Explain, with the aid of diagrams, what is meant by dominant-mode propagation in a rectangular waveguide.*

(*ii*) *What are the advantages of dominant-mode propagation?*

(*b*) *The wavelength measured in a waveguide energized in the dominant mode at a frequency of 6·25 GHz is found to be 8 cm. Calculate*

(*i*) *the critical wavelength for this mode, and*
(*ii*) *the frequency at which the guide wavelength becomes 10 cm.*

A3 (*b*) (*i*) The wavelength within the waveguide, that is the guide wavelength λ_g, is related to the free-space wavelength λ and the critical wavelength λ_c by the following

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}. \quad \ldots\ldots (1)$$

In the example, the guide wavelength λ_g is 8 cm at a frequency of 6·25 GHz. The free-space wavelength λ is defined as

$$\lambda = \frac{c}{f},$$

where c is the velocity of light and f is the frequency.

$$\therefore \quad \lambda = \frac{3 \times 10^8}{6\cdot25 \times 10^9} = 0\cdot048 \text{ m} = 4\cdot8 \text{ cm}.$$

From equation (1),

$$\frac{1}{\lambda_c^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_g^2},$$

$$= \frac{1}{(4\cdot8)^2} - \frac{1}{(8)^2} = \frac{1}{36},$$

$$\therefore \quad \lambda_c = \sqrt{36} = \underline{6 \text{ cm.}}$$

(*ii*) From equation (1),

$$\frac{1}{\lambda^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}.$$

The guide wavelength λ_g is 10 cm and the critical wavelength λ_c is 6 cm.

$$\therefore \quad \frac{1}{\lambda^2} = \frac{1}{10 \times 10} + \frac{1}{6 \times 6} = \frac{136}{3600}.$$

$$\therefore \quad \lambda = \sqrt{\left(\frac{3600}{136}\right)} = \underline{5\cdot145 \text{ cm.}}$$

Q4 (*a*) *With the aid of diagrams, explain what is meant by*

(*i*) *a TE wave, and*
(*ii*) *a TM wave.*

(*b*) *A 10·5 cm length of waveguide having a cross-section 4·25 × 2·05 cm is closed at both ends to form a resonant cavity. Fig. 1 (overleaf) shows the relation between free-space wavelength λ, critical wavelength λ_c and guide wavelength λ_g.*

Use this graph to determine

(*i*) *the lowest frequency of resonance (TE_{101} mode), and*
(*ii*) *the frequency at which TE_{102} resonance occurs.*

A4 (*a*) (*i*) A TE or transverse electric wave is one in which the electric field is perpendicular to the direction of wave propagation everywhere and has no electric component in the direction of travel. However, the associated magnetic field does have a component in the direction of propagation. A typical example of a TE wave is the dominant, TE_{10}, wave mode or lowest-order mode of propagation in rectangular waveguides, whose field components are shown in sketch (*a*).

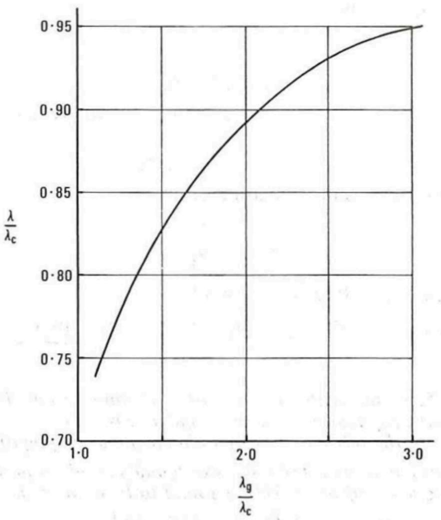
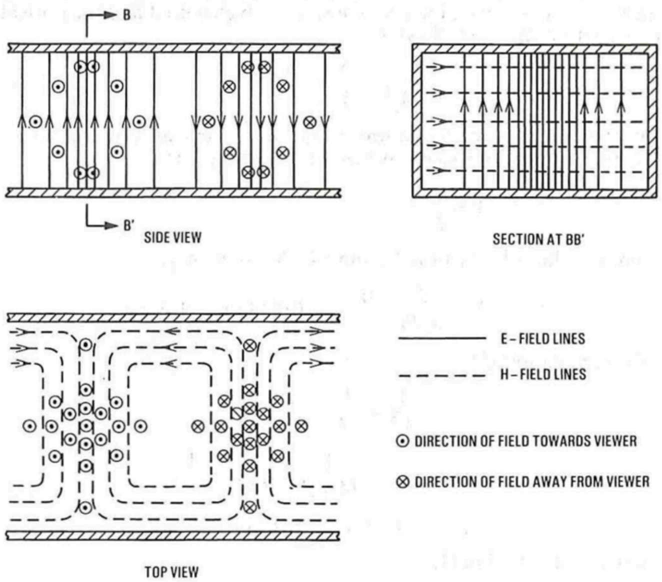
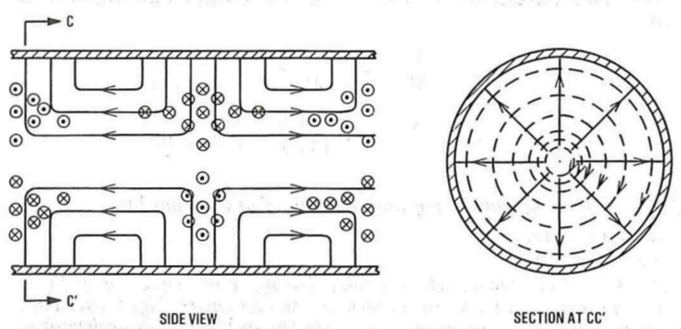


Fig. 1



(*a*)



(*b*)

(*ii*) A TM or transverse magnetic wave is one in which the magnetic field is perpendicular to the direction of wave propagation everywhere, and has no magnetic field component in the direction of travel. However, the associated electric field does have components in the direction of propagation. An example of a TM wave is the TM_{01} wave mode in circular waveguides, whose field components are shown in sketch (*b*). This waveguide mode is frequently encountered in microwave engineering in the rotating portion of a waveguide rotating joint, since the mode has field components possessing, in their pure form, perfect circular symmetry.

(*b*) (*i*) At the lowest frequency of resonance of the rectangular waveguide cavity in the TE_{101} mode, the length of the waveguide used is equal to one-half the guide wavelength; that is, the length of the cavity

$$= \lambda_g/2 = 10\cdot5 \text{ cm}.$$

With the given cross-section of the waveguide, the TE_{101} mode must be excited in such a way that the electric field is perpendicular to the longest dimension of the waveguide. The critical wavelength of the waveguide forming the cavity is given by twice this value; that is,

$$\lambda_c = 2 \times 4\cdot25 = 8\cdot5 \text{ cm}.$$

$$\therefore \quad \frac{\lambda_g}{\lambda_c} = \frac{21\cdot0}{8\cdot5} = 2\cdot47.$$

From Fig. 1, λ/λ_c is approximately 0·923 at the point where $\lambda_g/\lambda_c = 2\cdot47$.

$$\therefore \quad \frac{\lambda}{\lambda_c} = \frac{\lambda}{8\cdot5} = 0\cdot923.$$

$$\therefore \quad \lambda = 7\cdot85 \text{ cm}.$$

Therefore, the lowest frequency of resonance in the TE_{101} mode

$$= \frac{c}{\lambda} \text{ (where } c = \text{velocity of light)},$$

$$= \frac{3 \times 10^8}{7\cdot85 \times 10^{-2}} = 3\cdot82 \times 10^9 \text{ Hz} = \underline{3\cdot82 \text{ GHz}}.$$

(*ii*) When the TE_{102} mode of resonance is excited, the cavity is exactly one guide wavelength long; that is, $\lambda_g = 10\cdot5$ cm.

$$\therefore \quad \frac{\lambda_g}{\lambda_c} = \frac{10\cdot5}{8\cdot5} = 1\cdot235.$$

From the graph λ/λ_c is approximately 0·777 at the point where $\lambda_g/\lambda_c = 1\cdot235$.

$$\therefore \quad \frac{\lambda}{\lambda_c} = \frac{\lambda}{8\cdot5} = 0\cdot777.$$

$$\therefore \quad \lambda = 6\cdot605 \text{ cm}.$$

Therefore, the frequency at which the TE_{102} resonance occurs

$$= \frac{c}{\lambda} = \frac{3 \times 10^8}{6\cdot605 \times 10^{-2}} = \underline{4\cdot54 \text{ GHz}}.$$

Q5 (*a*) *By referring to the E-field and H-field configurations, explain the radiation pattern of a centre-fed $\lambda/2$ dipole in free space.*

(*b*) *Using this pattern explain*

(*i*) *why the $\lambda/2$ dipole has a gain factor, and*
(*ii*) *the beamwidth of this type of aerial.*

(*c*) *A microwave aerial which uses a paraboloidal reflector has at 6 GHz a gain of 39 dB and a beamwidth of 3·75°. Calculate the expected change in performance at 4·5 GHz.*

A5 (*b*) See A5(*a*), Basic Microwave Communication C 1978, *Supplement*, Vol. 72, p. 40, July 1979.

(*c*) The gain G of a microwave aerial using a paraboloidal reflector is proportional to its aperture area A, and is inversely proportional to the square of the operating wavelength λ; that is,

$$G \propto \frac{A}{\lambda^2}.$$

If the operating frequency changes from 6 to 4·5 GHz, and the aperture area of the reflector remains the same, the change in gain is given by the ratio

$$\frac{\text{gain of the aerial at } 4\cdot5 \text{ GHz}}{\text{gain of the aerial at } 6\cdot0 \text{ GHz}},$$

$$= \frac{(\text{wavelength at } 6\cdot0 \text{ GHz})^2}{(\text{wavelength at } 4\cdot5 \text{ GHz})^2},$$

$$= \frac{5^2}{6\cdot66^2} = 0\cdot563.$$

Therefore, the gain of the aerial is reduced to

$$39 - 10 \log_{10} 0\cdot563 \text{ dB},$$

$$= 39 - 2\cdot495 \approx \underline{36\cdot5 \text{ dB}}.$$

The beamwidth of a paraboloidal reflector aerial is proportional to wavelength and inversely proportional to aperture area. As in the

example above, the aperture area remains the same; therefore, the change in beamwidth is given by the ratio

$$\frac{\text{beamwidth at } 4\cdot 5 \text{ GHz}}{\text{beamwidth at } 6\cdot 0 \text{ GHz}},$$

$$= \frac{\text{wavelength at } 4\cdot 5 \text{ GHz}}{\text{wavelength at } 6\cdot 0 \text{ GHz}},$$

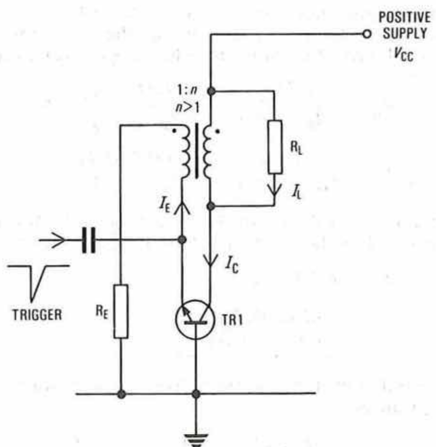
$$= \frac{6\cdot 66}{5} = 1\cdot 333.$$

Therefore, the beamwidth at 4·5 GHz will be 1·333 times that at 6 GHz; that is, 5°.

Q6 (*a*) *With the aid of a circuit diagram and time-related waveforms, explain the action of a triggered blocking oscillator which uses a transistor in the common-base configuration.*

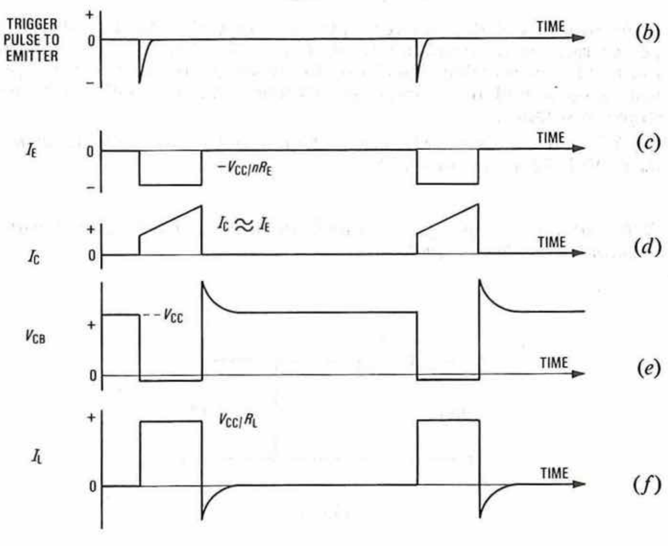
(*b*) *Explain how the duration of the pulses generated by this oscillator could be varied.*

A6 (*a*) Sketch (*a*) shows a simple triggered blocking oscillator using an n p n transistor in the common-base mode.



(*a*)

The circuit is triggered at $t = 0$ by a negative trigger pulse which initiates current flow in the transistor TR1. Collector current begins to flow (see sketch (*d*)), and the collector voltage, V_{CB}, falls, as shown in sketch (*e*). The falling collector voltage is coupled through the transformer to make the emitter voltage fall also; this increases the current in the transistor and further reduces the collector voltage. This regenerative action continues until the collector voltage can fall no further; that is, the transistor is saturated. The circuit would remain in this condition if it were not for the magnetizing inductance of the transformer. To maintain the full value of V_{cc} across the secondary of the transformer requires the magnetizing current to rise linearly with time. However, the value of the emitter current is limited and fixed, and after a time the collector current tries to exceed the value of the



emitter current (see sketches (*c*) and (*d*)). Such a condition cannot occur, and, at this time, the circuit will switch out of the saturated state and out of conduction. The circuit generates a pulse with a magnitude equal to the supply voltage V_{cc}, and with a length determined largely by the design of the transformer.

(*b*) The duration of the pulses generated by the blocking oscillator can be changed by designing the transformer core material to saturate at greater or lesser magnetizing currents. A transformer which saturates at low levels of current reduces the duration of the output pulse and vice versa.

Q7 (*a*) *Fig. 2 below is the block diagram of an FM modulator.*

(*i*) *Draw phasor diagrams showing relationships of the frequency components present at A and at B, with the 1 MHz input.*

(*ii*) *State why the audio equalizer requires an inverse frequency characteristic.*

(*iii*) *Why is the modulation index of the output much less than unity?*

(*b*) *Explain, with the aid of a block diagram, how the output of this modulator could be used to provide wide deviation of a crystal-controlled 100 MHz transmitter.*

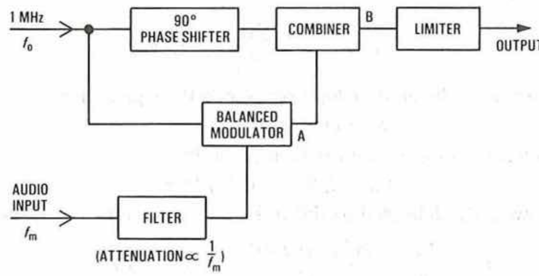


Fig. 2

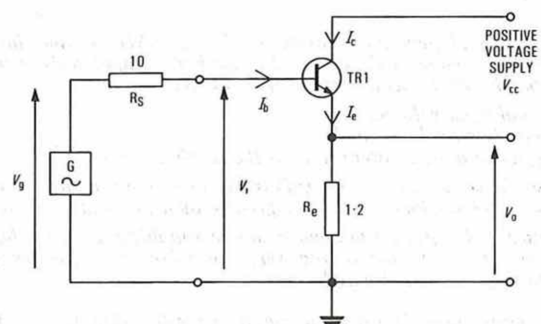
Q8 (*a*) *Draw a circuit diagram of an emitter follower amplifier.*

(*b*) *The transistor used in an emitter follower amplifier has an α value of 0·98. The load resistance is 1·2 kΩ. The input to this circuit is a signal generator which has an internal resistance of 10 kΩ. Calculate approximate values of the*

(*i*) *input resistance which the amplifier presents to the signal source,*
(*ii*) *output impedance of the amplifier,*
(*iii*) *current gain of the amplifier, and*
(*iv*) *power gain of the amplifier.*

(*c*) *Referring to the results of part* (*b*) *above, state* TWO *applications of the emitter follower in microwave communications practise.*

A8 (*a*) The sketch shows the circuit diagram of a simple emitter follower amplifier using an n p n transistor with an emitter load resistance of 1·2 kΩ. The generator has an internal resistance of 10 kΩ.



(*b*) In the example, α represents the ratio of collector current I_c to emitter current I_e; that is, I_c/I_e. In the calculations that follow the forward current transfer ratio of the transistor is used. This ratio, I_c/I_b, is termed β and is related to α by

$$\beta = \frac{\alpha}{1-\alpha}.$$

For the transistor in the example, $\beta = \dfrac{0{\cdot}98}{1-0{\cdot}98} = 49.$

(*i*) The input impedance that the emitter follower amplifier presents to the signal source is approximately, $(1+\beta)R_e$, where R_e is the emitter load resistance. Therefore, the input impedance, R_{in}, is approximately equal to $(1+49)\times 1200 = \underline{60\ \text{k}\Omega}$.

(*ii*) As the output impedance of the transistor (that is, the collector-to-earth resistance) is high when compared with R_e, the output impedance R_O is approximately equal to R_e; that is, $R_O \approx \underline{1{\cdot}2\ \text{k}\Omega}$.

(*iii*) The current gain of the amplifier is approximately equal to the ratio of the emitter current to the base current I_b; that is, I_e/I_b.

Since $\qquad I_e = I_c + I_b,$

then $\qquad \dfrac{I_e}{I_b} = \dfrac{I_c}{I_b} + 1 = \beta + 1,$

$$= \underline{50.}$$

(*iv*) The voltage, V_i, across the input terminals of the amplifier is given by

$$V_i = I_b R_{in}.$$

The power, P_i, delivered to the transistor from the signal source is given by

$$P_i = \frac{V_i^2}{R_{in}} = \frac{I_b^2 R_{in}^2}{R_{in}} = I_b^2 R_{in}.$$

The current in the emitter load resistance R_e is given by

$$I_e = (1+\beta)I_b.$$

Therefore, the output voltage V_O is given by

$$V_O = I_e R_e = (1+\beta)I_b R_e.$$

The power, P_O, delivered to the emitter load-resistance is given by

$$P_O = \frac{V_O^2}{R_e} = \frac{(1+\beta)^2 I_b^2 R_e^2}{R_e} = (1+\beta)^2 I_b^2 R_e.$$

The power gain of the amplifier is given by the ratio

$$\frac{\text{power delivered to the load}}{\text{power delivered to the amplifier from the source}},$$

$$= \frac{P_O}{P_i} = \frac{(1+\beta)^2 I_b^2 R_e}{I_b^2 R_{in}} = \frac{(1+\beta)^2 R_e}{R_{in}},$$

$$= \frac{(1+49)^2 \times 1{\cdot}2 \times 10^3}{60 \times 10^3},$$

$$= \underline{50.}$$

(*c*) Because the emitter follower amplifier effectively transforms a high input impedance to a low output impedance, such an amplifier can be used in microwave communications practice as an impedance matching stage between the output of an intermediate frequency amplifier and a low impedance cable link. Another application, where the low output impedance of the emitter follower amplifier may be found useful, is as a p i n modulator drive stage. The high impedance of the diodes is heavily damped by the emitter follower driver circuit, and, therefore, the noise contribution of the diodes in the circuit is lowered.

Q9 (*a*) *A signal generator having an RMS EMF E and internal resistance R_S, is connected to a receiver having an input resistance R_R. For a bandwidth B, deduce expressions for the*

(*i*) *signal input voltage,*
(*ii*) *noise input voltage, and*
(*iii*) *signal-to-noise (power) ratio at the receiver input.*

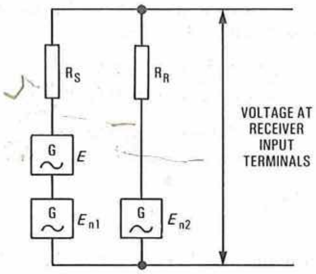
(*b*) *Use the results at part (a) (iii) above to explain the advantage of making the receiver input resistance greater than the source resistance.*

(*c*) *Describe briefly, a white-noise source suitable for measuring the noise factor of a microwave receiver. State how the effective noise temperature of the source may be varied.*

A9 The equivalent circuit of a signal generator that has an RMS EMF E and internal resistance R_S, and is connected to a receiver with an input resistance R_R and bandwidth B Hz, is shown in the sketch. The additional voltage sources E_{n1} and E_{n2} are shown because of the thermal noise generated by each resistor in the circuit.

(*i*) The current, I, flowing through R_R, due to the signal component E, is given by

$$I = \frac{E}{R_R + R_S}.$$



Therefore, the signal input voltage, E_S, at the input terminals of the receiver is given by

$$E_S = \frac{ER_R}{(R_R + R_S)}.$$

(*ii*) The RMS thermal noise voltage, E_n, developed by a resistor R at a temperature T K in a bandwidth B Hz was shown by Nyquist to be related by,

$$E_n = (4kTBR)^{\frac{1}{2}},$$

where k = Boltzmann's constant $= 1{\cdot}38 \times 10^{-23}$ J/K.

The RMS noise voltages, E_R and E_S, at the input terminals of the receiver, due to the resistances R_R and R_S, respectively, are as follows:

$$E_R = \frac{E_{n1}R_R}{(R_R+R_S)} = \frac{(4kTBR_S)^{\frac{1}{2}}R_R}{(R_R+R_S)}.$$

$$E_S = \frac{E_{n2}R_S}{(R_R+R_S)} = \frac{(4kTBR_R)^{\frac{1}{2}}R_S}{(R_R+R_S)}$$

Since these 2 noise voltages are RMS voltages, the total RMS noise voltage, E_n, present at the receiver terminals, is given by

$$E_n = (E_R^2 + E_S^2)^{\frac{1}{2}},$$

$$= \underline{\left\{\frac{4kTBR_R R_S}{(R_R+R_S)}\right\}^{\frac{1}{2}}}.$$

(*iii*) The signal power available at the receiver input is given by, $S_i = E_S^2/R_R$; that is,

$$S_i = \frac{E^2 R_R^2}{(R_R+R_S)^2} \times \frac{1}{R_R} = \frac{E^2 R_R}{(R_R+R_S)^2}.$$

The noise power, N_i, is obtained in the same fashion from E_n (the sum of the noise voltage components from the resistors in the circuit). Therefore $N_i = E_n^2/R_R$; that is,

$$N_i = \frac{4kTBR_R R_S}{(R_R+R_S)} \times \frac{1}{R_R}.$$

Therefore, the ratio of the signal-to-noise power at the receiver input, S_i/N_i, is given by

$$\frac{S_i}{N_i} = \frac{E^2 R_R}{(R_R+R_S)} \times \frac{(R_R+R_S)}{4kTBR_S}$$

$$= \underline{\frac{E^2 R_R}{4kTBR_S(R_R+R_S)}}.$$

(*b*) In terms of the receiver input resistance R_R, the signal-to-noise power ratio is proportional to $R_R/(R_R + R_S)$. Therefore, to obtain the maximum possible signal-to-noise power ratio, the receiver input resistance should be as large as possible compared with the signal source resistance.

(*c*) See A7(*a*), Basic Microwave Communications C 1978, *Supplement*, Vol. 72, p. 41, July 1979.

Q10 (*a*) *Fig. 3 represents a simple filter for demodulating a pulse-amplitude modulated signal.*

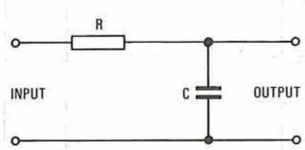


Fig. 3

(*i*) *Show that the cut-off frequency of this filter is given by*

$$f_0 = \frac{1}{2\pi CR}.$$

(*ii*) *The ratio of output to input voltage at a frequency f well above the cut-off frequency is*

$$\frac{1}{\sqrt{\left(1+\frac{f}{f_0}\right)^2}}.$$

Calculate the ratio of output to input voltages at $f = 4f_0$ and at $f = 8f_0$.

(*b*) *A train of short duration pulses recurring at intervals of 80 μs is amplitude modulated by a 7 kHz tone. The resulting signal is demodulated by a filter of the type shown in Fig. 3. Assuming $R = 25\ k\Omega$ and $C = 600\ pF$, state with reasons, the frequencies of the output components that have been attenuated by less than 3 dB.*

A10 (*a*) (*i*) The gain, A, of the circuit shown in Fig. 3, at frequency f, where $\omega = 2\pi f$, is given by

$$A = \frac{\text{output voltage across C}}{\text{input voltage}},$$

$$= \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}},$$

$$= \frac{1}{R + j\omega CR},$$

$$= \frac{1}{R + j\omega CR} \times \frac{1 - j\omega CR}{1 - j\omega CR},$$

$$= \frac{1}{1 + \omega^2R^2C^2} - j\frac{\omega CR}{1 + \omega^2R^2C^2}.$$

The amplitude of the gain is given by

$$|A| = \left\{\frac{1 + \omega^2R^2C^2}{(1 + \omega^2R^2C^2)^2}\right\}^{\frac{1}{2}},$$

$$= \frac{1}{(1 + \omega^2R^2C^2)^{\frac{1}{2}}}.$$

The cut-off frequency of the filter corresponds to the point where the gain has fallen by 3 dB; that is, the amplitude is $1/\sqrt{2}$ of its value at $\omega = 0$. Therefore, at this point $A = 1/\sqrt{2}$.

Hence,

$$\frac{1}{\sqrt{2}} = \frac{1}{(1 + \omega^2R^2C^2)^{\frac{1}{2}}}.$$

$$\therefore \quad \omega^2R^2C^2 = 1.$$

$$\therefore \quad \omega = \frac{1}{CR}.$$

$$\therefore \quad f_0 = \frac{1}{2\pi CR}.$$

(*ii*) When $f = 4f_0$, the ratio of the output to the input voltage is

$$\frac{1}{\{1 + (4f_0/f_0)^2\}^{\frac{1}{2}}} = \frac{1}{(1 + 16)^{\frac{1}{2}}} = \underline{0 \cdot 243.}$$

When $f = 8f_0$, the ratio of the output to input voltage is

$$\frac{1}{\{1 + (8f_0/f_0)^2\}^{\frac{1}{2}}} = \frac{1}{(1 + 64)^{\frac{1}{2}}} = \underline{0 \cdot 124.}$$

(*b*) When a 7 kHz signal is sampled by a pulse train with a pulse repetition period of 80 μs (that is, a pulse repetition frequency of 12·5 kHz) the resultant frequency spectrum contains the following components:

(*i*) A component at the sampled signal frequency, f_m; that is, 7 kHz.
(*ii*) Components at $n \times f_p \pm f_m$, where f_p is the pulse repetition frequency of 12·5 kHz, and n is an integer with an initial value of 1.

When the filter shown in Fig. 3 is used, with component values $R = 25\ k\Omega$, and $C = 600$ pF, the cut-off frequency, where the magnitude of the gain falls to -3 dB of its value at 0 Hz, is given by

$$f_0 = \frac{1}{25000 \times 600 \times 10^{-12} \times 2\pi} = 10 \cdot 61 \text{ kHz}.$$

Therefore, 2 components of the above frequency spectrum are attenuated by less than 3 dB. These are the components whose frequencies are less than 10·61 kHz, which are as follows:

(*i*) the sampled signal frequency, f_m, at 7 kHz; and
(*ii*) the lower sideband of the first set of modulated sampling frequency components, $f_p - f_m = 5 \cdot 5$ kHz.

SCOTTISH TECHNICAL EDUCATION COUNCIL

Certificate in Electrical and Electronic Engineering

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INTRODUCTION TO TELECOMMUNICATIONS SYSTEMS 1981

Students were expected to attempt all questions in Section A and 3 questions from Section B

SECTION A

Q1 Calculate the frequency of a waveform whose velocity of propagation is 3×10^8 m/s and whose wavelength is 300 m.

A1
$$\text{Frequency} = \frac{\text{velocity of propagation}}{\text{wavelength}},$$

$$= \frac{3 \times 10^8}{300},$$

$$= \underline{10^6 \text{ Hz or } 1 \text{ MHz.}}$$

Q2 Name the telephone switching system which uses single input, multiple outlet switches.

A2 Strowger.

Q3 In which of the 2 systems, analogue or digital, is regeneration used?

A3 Digital.

Q4 State the line parameter which limits the range of direct current signalling.

A4 Resistance.

Q5 How many communication channels, each of 4 kHz bandwidth, can be accommodated in a circuit operating in the range of 30 kHz to 46 kHz?

A5
$$\text{Number of channels} = \frac{\text{circuit bandwidth}}{\text{channel bandwidth}},$$

$$= \frac{46 - 30}{4} = \underline{4 \text{ channels.}}$$

Q6 *Name* ONE *type of Telex exchange.*

A6 Area exchange or zone centre exchange.

Q7 *State the modulation method which produces sideband frequency components?*

A7 Amplitude modulation.

Q8 *In amplitude modulation, what is varied by varying the amplitude of the modulating signal?*

A8 The depth of modulation.

Q9 *Name the type of modulation which is used for television sound broadcasting.*

A9 Frequency modulation.

Q10 *Fig. 1 shows 2 waveforms. State the phase relationship of waveform A with respect to waveform B.*

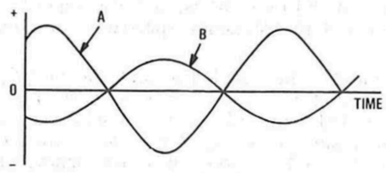


Fig. 1

A10 Waveform A leads (or lags) waveform B by 180°, or π radians (or A is in anti-phase to B).

Q11 *Name the type of microphone which is normally used as the transmitter in a telephone handset.*

A11 The microphone that is most widely used at present as the transmitter in a telephone handset is the carbon granule microphone.

Q12 *Fig. 2 shows a modulated waveform. Name this type of modulation.*

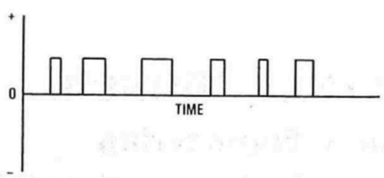


Fig. 2

A12 Pulse-width modulation.

Q13 *Which multiplexing method reconstitutes waveforms from regularly sampled amplitudes?*

A13 Time-division multiplexing.

Q14 *Name the type of telephone cable which has the greatest frequency bandwidth.*

A14 Coaxial cable (or optical fibre).

Q15 *Can radio waves be propagated through a vacuum?*

A15 Yes.

Q16 *Name the part of the telephone network which caters for trunk calls which cannot be routed over the normal main network because of excessive losses and delays.*

A16 Transit network.

Q17 *State the maximum possible number of simultaneous conversations through a 10-inlet, 7-outlet matrix switch.*

A17 The number of possible simultaneous conversations is the lesser of the number of inlets or outlets. Hence the answer is 7.

Q18 *How many scan lines are used in the UK television system?*

A18 On the older system 405 lines are used, and in the more recent system 625 lines are used.

Q19 *Name the type of modulation which is used for television video signals.*

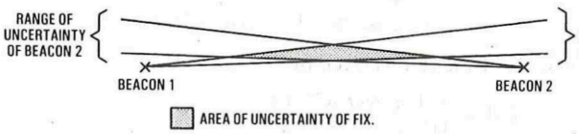
A19 Amplitude modulation.

Q20 *In a television set which has the higher frequency, line or frame time base?*

A20 Line time base.

Q21 *If radio beacons are to be employed to provide a navigation aid over a certain area, what is the minimum number of beacons required to give a reasonably accurate position fix?*

A21 Three beacons. [*Tutorial Note*: Two beacons give a reasonably accurate fix for most occasions except close to the line between the beacons (see sketch).]



Q22 *Name the part of the telephone instrument which is used to control the stepping of switches in a sequential stepping system.*

A22 The dial impulsing contacts (for a dial telephone).

Q23 *Which electrode in a CRT controls electron beam intensity by varying its potential with respect to the cathode?*

A23 The grid.

Q24 *Name the code used for digital signals in a PCM system.*

A24 Binary code.

Q25 *Which factor, indicating quality of a transmission line, is measured in decibels?*

A25 Signal-to-noise ratio (ratio of signal power to noise power).

SECTION B

Q26 (*a*) *A single sinusoidal note, produced by a tuning fork, is picked up by a microphone 20 m away. At the microphone the sound wave has pressure peaks of 2 units of pressure and a wavelength of 94·86 mm. If a microphone has an electrical ouput of 2 mV/unit pressure sketch the analogue electrical output voltage waveform from the microphone indicating peak voltage and frequency.*

(*b*) *How long does the sound wave take to travel from the tuning fork to the microphone?*

(*c*) *What is the time interval between successive pressure peaks reaching the microphone?*

(*d*) *Figure 3 shows a simplified moving coil loudspeaker. Name parts 1 to 4 and give an explanation of the theory of operation of the loudspeaker.*

A26 (*a*) The output electrical signal from a microphone is an analogue signal of the input waveform (that is, the same shape and frequency).

Peak voltage = pressure peak × microphone output per unit pressure,

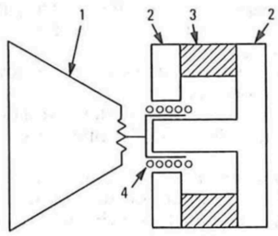


Fig. 3

$= 2 \times 2,$
$= 4$ mV.

Frequency of electrical waveform = frequency of sound waveform,

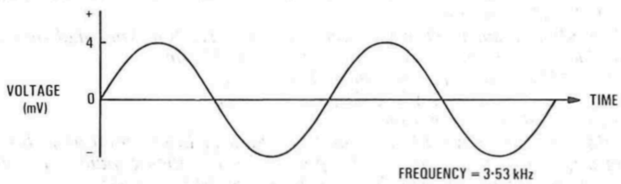
$$= \frac{\text{velocity of propagation}}{\text{wavelength}},$$

(the velocity of propagation of sound waves in air was given as 335 m/s)

$$= \frac{335}{94{\cdot}86 \times 10^{-3}},$$

$$= 3{\cdot}53 \text{ kHz}.$$

The sketch below shows the electrical waveform from the microphone.



(*b*) Time for sound wave to travel from the timing fork to the microphone $= \frac{\text{distance travelled}}{\text{velocity of propagation}}$,

$$= \frac{20}{335},$$

$$= \underline{59{\cdot}7 \text{ ms.}}$$

(*c*) Pressure peaks leave the timing fork with a frequency of 3·53 kHz; that is, 3530 peaks leave the fork each second.

Therefore, the time between successive peaks reaching the microphone $= \frac{1}{3530} = \underline{0{\cdot}283 \text{ ms.}}$

(*d*) (1) Diaphragm
(2) Pole pieces
(3) Ring type permanent magnet
(4) Coil

Signal current flowing in coil 4 sets up a magnetic field which reacts with the fixed magnetic field between the pole pieces. Current flowing through the coil in one direction therefore results in deflection of the coil (and diaphragm), say to the left, the amount of deflection being proportional to the instantaneous current in the coil. If the signal current is reversed, the coil and diaphragm is deflected in the opposite direction. An alternating electrical signal current flowing in the coil therefore gives rise to proportional movements of the diaphragm which produce analogue compressions/rarefractions of the air in the vicinity of the diaphragm, and hence sound.

Q27 (*a*) *Figures 4(a), 4(b) and 4(c) show respectively a sinusoidal modulating signal, a high-frequency sinusoidal carrier wave (carrier 1) and a pulse carrier wave (carrier 2). On the axes provided, sketch the following modulated waveforms:*

(*i*) *amplitude modulation,*
(*ii*) *frequency modulation,*
(*iii*) *pulse-amplitude modulation,*
(*iv*) *pulse-width modulation, and*
(*v*) *pulse-position modulation.*

(*Note: The student was provided with 5 sets of axes similar to Fig. 4(d). To save space only one set of axes, Fig. 4(d), is printed*).

(*b*) *Sketch a frequency/amplitude plot for a high-frequency sinusoidal carrier wave of frequency f_c Hz, modulated by a complex signal having frequency components in the range f_{min} to f_{max}. Mark all important frequencies on the plot and state the bandwidth limits of the modulated signal.*

(*c*) *State the basic differences between the three main multiplexing methods and give a practical example of the use of each method in telecommunications.*

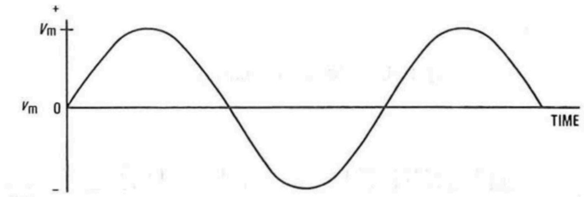


Fig. 4(a) Modulating signal

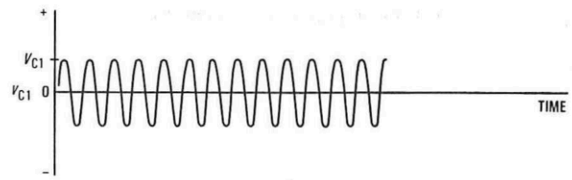


Fig. 4(b) HF sinusoidal carrier

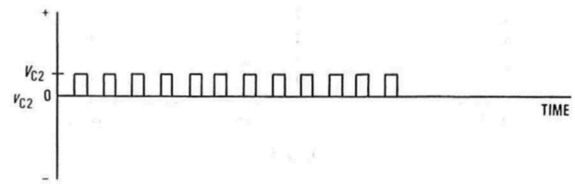


Fig. 4(c) Pulse carrier

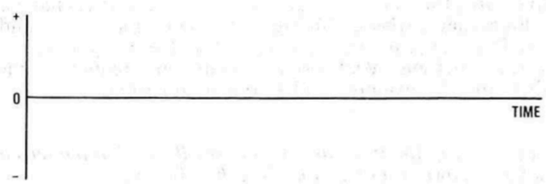
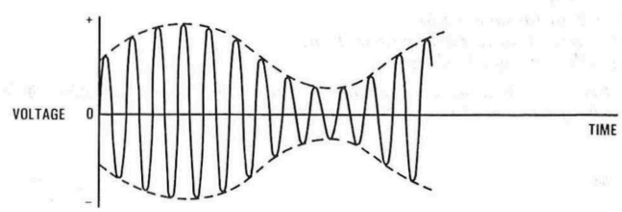
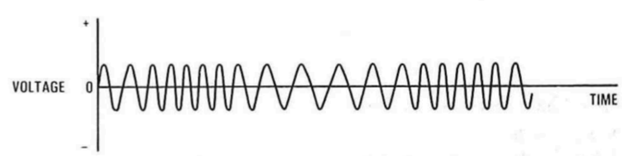


Fig. 4(d)

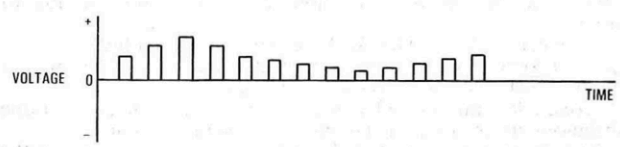
A27 (*a*)



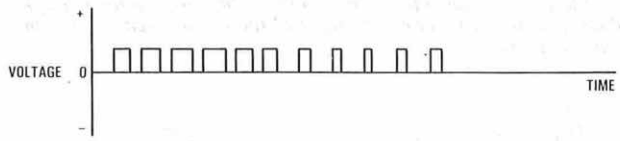
(*i*) Amplitude modulation



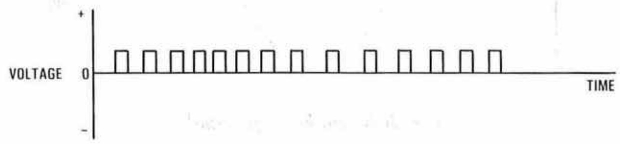
(*ii*) Frequency modulation



(*iii*) Pulse-amplitude modulation

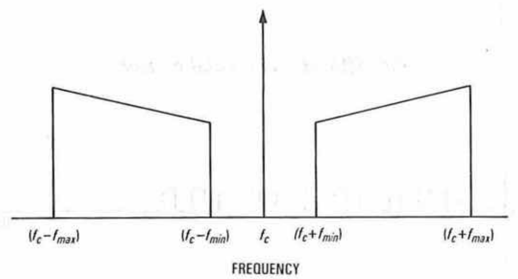


(*iv*) Pulse-width modulation



(*v*) Pulse-position modulation

(*b*)



Bandwidth limits are from $(f_c - f_{max})$ to $(f_c + f_{max})$.

(*c*) (*i*) **Space-Division Multiplexing:** common time and frequency, exclusive path; for example, trunking in a telephone exchange.

(*ii*) **Frequency-Division Multiplexing:** common time and path, exclusive frequency; for example, carrier-system telephony.

(*iii*) **Time-Division Multiplexing:** common frequency and path, exclusive time; for example, pulse-code modulation.

Q28 (*a*) *Identify the types of cables normally used in the telecommunications links shown in Fig. 5; that is, cables* (*i*) *to* (*iii*).

(*b*) *Briefly explain the following terms with reference to telecommunication networks:*

(*i*) *attenuation;*
(*ii*) *amplifier;*
(*iii*) *thermal noise;*
(*iv*) *crosstalk;*
(*v*) *signal-to-noise ratio;*
(*vi*) *attenuation/frequency distortion;*
(*vii*) *delay/frequency distortion.*

(*c*) *List* THREE *modes of propagation for radio waves and give their respective frequency classification groups.*

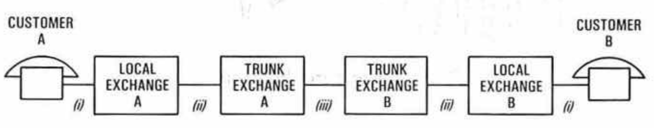


Fig. 5

A28 (*a*) The types of cable are

(*i*) pair cable,
(*ii*) quad cable, and
(*iii*) coaxial cable.

(*b*) (*i*) **Attenuation** is the reduction in signal amplitude due to circuit parameters.

(*ii*) An **amplifier** is a device for boosting signal amplitude.

(*iii*) **Thermal noise** is unwanted electrical signals caused by random motion of free electrons due to thermal agitation.

(*iv*) **Crosstalk** is an induced signal from a neighbouring circuit due to unbalanced electromagnetic coupling between the circuits.

(*v*) The **signal-to-noise ratio** is the ratio of the signal power to the noise power. It is a measure of the quality of a communication channel.

(*vi*) **Attenuation/frequency distortion** is the distortion of a multi-frequency signal due to varying degrees of attenuation for the different frequency components.

[*Tutorial note:* Higher-frequencies are more severely attenuated than lower-frequency components.]

(*vii*) **Delay/frequency distortion** is the distortion of multi-frequency signals due to different velocities of propagation for different frequency components.

[*Tutorial note:* Higher-frequency components travel slower down electrical circuits than lower-frequency components, so the different frequency components take different times to travel the same distance.]

(*c*) the 3 modes of propagation for radio waves are

(*i*) ground waves (low frequency),
(*ii*) ionospheric waves (high frequency), and
(*iii*) space waves (very high frequency).

Q29 (*a*) *A particular telephone customer wishes to call another customer but they are located such that, if the normal trunk network was used, the call would have to pass through more than 2 trunks in tandem.*

Draw a block diagram to show how the call can be made indicating ALL CONNECTION AND SWITCHING POINTS *which could be involved, starting from one customer's premises and terminating in the other.*

(*b*) *See Fig. 6.*
What is indicated by EACH *of the following conditions:*

(*i*) *DC flows in line A;*
(*ii*) *DC plus superimposed 50 Hz AC flows in line A;*
(*iii*) *DC in line A is regularly interrupted 9 times* (*at 10 pulses/s*) *and the 50 Hz AC is removed;*
(*iv*) *after a short delay an interrupted 400 Hz tone* (*unequal on and off periods*) *is superimposed on the DC current in line A;*
(*v*) *DC in line A is disconnected for 2 min;*
(*vi*) *sequences* (*i*), (*ii*) *and* (*iii*) *are repeated;*
(*vii*) *DC flows in junction x;*
(*viii*) *DC in line A and junction x is regularly interrupted as follows: 3 times then a pause, twice then a pause, 5 times then a pause, 4 times then a pause, then 7 times* (*all interruptions at 10 pulses/s*)*;*
(*ix*) *after a short delay a tone, consisting of a combination of 400 Hz and 450 Hz, is applied to line A;*
(*x*) *at the same time a 25 Hz AC signal is applied to line B;*
(*xi*) *after a few seconds DC flows in line B and the 25 Hz AC is removed;*
(*xii*) *the DC in junction x reverses direction?*

(*c*) *Name the 2 types of telephone exchange which use matrix switching stages.*

(*d*) *If the efficiency of a matrix switch is found by dividing the maximum number of possible simultaneous calls through the switch by the number of crosspoints, what is the efficiency of a 10-inlet, 8-outlet switch?*

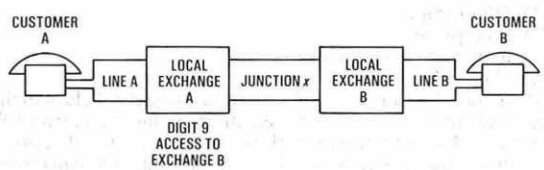
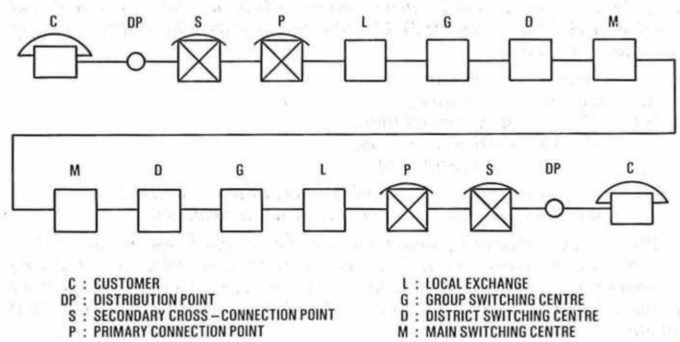


Fig. 6

A29 (*a*)



(*b*) (*i*) Customer A lifts handset to complete DC loop.
(*ii*) Dial tone applied to Customer A's line.
(*iii*) Customer A dials digit 9.
(*iv*) Equipment engaged tone returned to Customer A (no spare junctions to Exchange B).
(*v*) Customer A replaces handset and waits 2 min.
(*vi*) Customer A lifts handset and dials digit 9.
(*vii*) Exchange secures junction x for Customer A's call and switching equipment in exchange B is ready to accept call.
(*viii*) Customer A dials 32547.
(*ix*) Ringing tone is returned to Customer A.
(*x*) Ringing current is applied to Customer B's line.
(*xi*) Customer 32547 answers call by lifting handset.
(*xii*) Current is reversed in junction x to signal exchange A that the call has been answered.

(*c*) Electronic and crossbar exchanges.

(*d*) $$\text{Efficiency} = \frac{\text{maximum possible number of simultaneous calls}}{\text{number of crosspoints}},$$

$$= \frac{8}{80} = \underline{0{\cdot}1 \text{ or } 10\%.}$$

Q30 *Fig. 7 shows part of a video section of a television receiver.*

(*a*) *State the names and functions of blocks 1 to 5.*

(*b*) *Explain fully how the circuit can transform a composite video signal into an illuminated picture on the CRT screen. (Note: your answer should include a detailed description of the operation of the CRT.)*

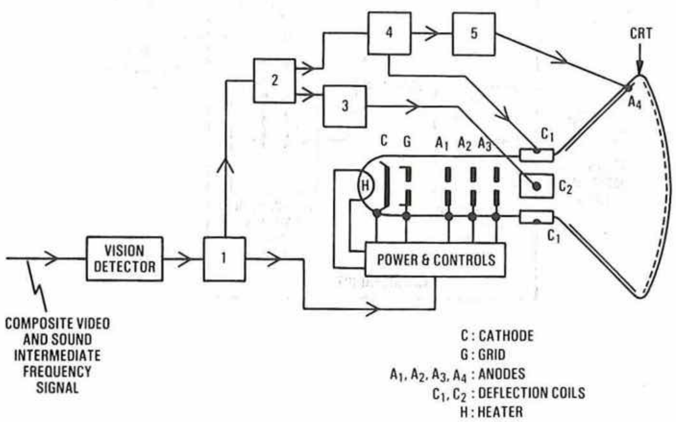


Fig. 7

A30 (*a*) (1) **Video amplifier:** used to boost the video signal.
(2) **Synchronization separator:** extracts the line and frame synchronization pulses from the composite signal.
(3) **Frame time-base circuit:** used to generate the sawtooth waveform for the vertical deflection coils.
(4) **Line time-base circuit:** used to generate the sawtooth waveform for the horizontal deflection coils.
(5) **EHT generator:** used to generate the very high voltage for the final anode of the CRT.

(*b*) Composite video plus sound signals enter the vision detector where they are separated and the video signal is demodulated. The video signal is then boosted in the video amplifier. After amplification the synchronization pulses are extracted by the synchronization separator and the video signal passes onto the CRT. The line and frame synchronization pulses are used to trigger the line and frame time-base circuits. The line time-base circuit is also used in conjunction with the EHT generator circuit to produce a very high final anode voltage.

In the CRT, a cathode filament is heated and releases electrons. These negatively charged electrons are attracted towards anodes which are held at positive potentials with respect to the cathode. The final anode (A4) is the one which causes the electrons to accelerate rapidly towards the screen (typically several kilovolts are provided).

When the electrons impinge on the phosphorescent screen, their high kinetic energy is converted into visible light.

The anodes A1 to A3 are arranged to focus the electron beam so that, for no deflection signals, a bright spot appears on the centre of the screen.

If the grid is made more negative than the cathode, this tends to repel electrons; thus, control of the grid-cathode potential controls beam strength and hence light intensity of the spot on the screen. The video signal is in fact used to control this potential and so amplitude variations of the video signal (representing light intensity variations of the televised scene) results in variations of light intensity on the screen. The time-base circuits generate sawtooth current waveforms for the horizontal and vertical deflection coils which deflect the beam horizontally and vertically to produce a series of scan lines in synchronization with the scan pattern of the television camera. The instantaneous variations of video signal amplitude thus recreates the televised scene.

Q31 (*a*) *Draw a block diagram of a simple radar system and explain the function of each block.*

(*b*) *In a PPI radar system, explain how the electron beam scan rotates round the screen and how the presence of an object is depicted on the CRT screen.*

(*c*) *Fig. 8 shows the display of a transmit and echo pulse from a certain object in the range of the radar system. If the radar system operates with a scan time-base frequency of 25 kHz, calculate how far the object is from the aerial.*

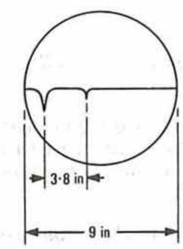
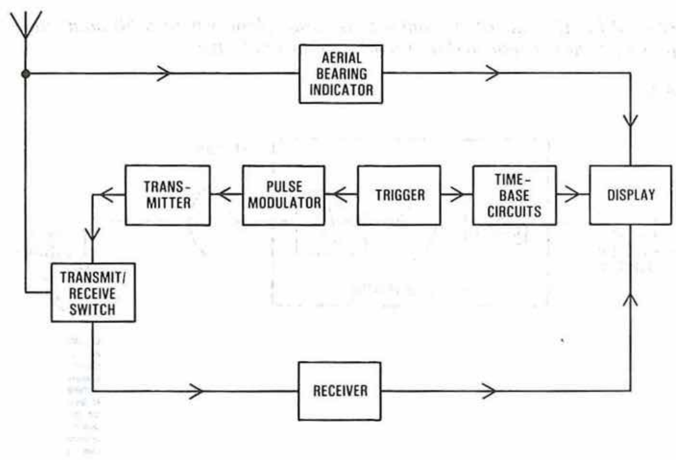


Fig. 8

A31 (*a*)



Display This gives a visual indication of range and bearing.

Time-Base Circuits These are used to control the deflection of the electron beam in the CRT (via deflection coils).

Trigger This triggers the pulse modulator and the time-base circuits.

Pulse Modulator This is used to pulse the transmitter ON and OFF

Transmitter This produces high frequency oscillations of radio power when switched by the pulse modulator.

Transmit/Receive Switch This connects the transmitter to the aerial during transmission, and the receiver to the aerial to receive echoes. It also prevents the high transmit power from reaching the receiver.

Receiver This receives, amplifies and passes echo pulses for the display system.

(*b*) In a PPI radar system the electron beam scans from the centre out to the perimeter of the screen and at the same time the scan line is slowly rotated round the screen under the influence of the deflection coils in synchronism with the aerial. The presence of an object is depicted on the screen by a bright area.

(*c*) Time for beam to scan across screen

$$= \frac{1}{\text{time-base frequency}},$$

$$= \frac{1}{25 \times 10^3}\text{ s.}$$

The time taken to scan 9 inches of screen is $\frac{1}{25 \times 10^3}$ s.

The time taken to scan $3 \cdot 8$ inches of screen is $\frac{3 \cdot 8}{9} \times \frac{1}{25 \times 10^3}$ s.

This represents the time taken for a pulse being transmitted from the aerial and the echo pulse being received back from the object; that is $\frac{3 \cdot 8}{9 \times 25 \times 10^3}$ s is the time for radio waves to travel from the radar set to the object and back.

Therefore, the time for waves to travel to the object

$$= \tfrac{1}{2} \times \frac{3 \cdot 8}{9 \times 25 \times 10^3} = 8 \cdot 44 \times 10^{-6}\text{ s.}$$

Therefore, the distance of the object from the screen

$$= \text{velocity of propagation} \times 8 \cdot 44 \times 10^{-6},$$

(the velocity of propagation of electromagnetic radiation was given as 3×10^8 m/s)

$$= 3 \times 10^8 \times 8 \cdot 44 \times 10^{-6},$$

$$= \underline{2 \cdot 532\text{ km.}}$$

SWITCHING SYSTEMS III 1981

Students were expected to attempt all questions in Section A and 4 questions from Section B.

SECTION A

Q1 *What is meant by the term overall grade of service in a Non-Director exchange?*

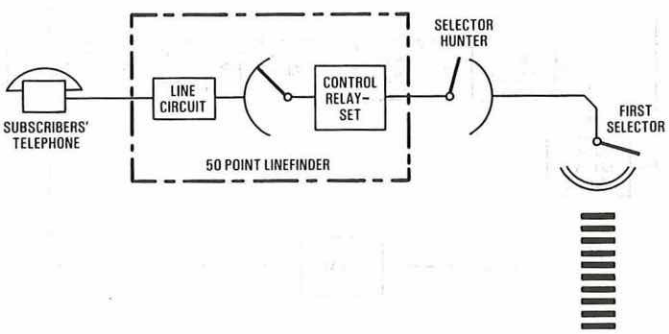
A1 Each switching stage in the exchange has its own grade of service. The *overall* grade of service is calculated from the total number of calls lost over a number of switching stages combined together in series.

Q2 *Explain why a full availability group carries more traffic than a graded group, assuming each group has the same number of trunks.*

A2 In a full availability group, every outlet (trunk) is available to every traffic source. However, in a graded group the early choice single trunks are only available to certain sources. Hence, there could be congestion in one section while trunks were unused elsewhere in the group.

Q3 *With the aid of a trunking diagram show where a 50-point line-finder group is connected in a non-director exchange.*

A3



Q4 *Explain why, when a local call is set up in a Director area, anything from one to six routeing digits may be required.*

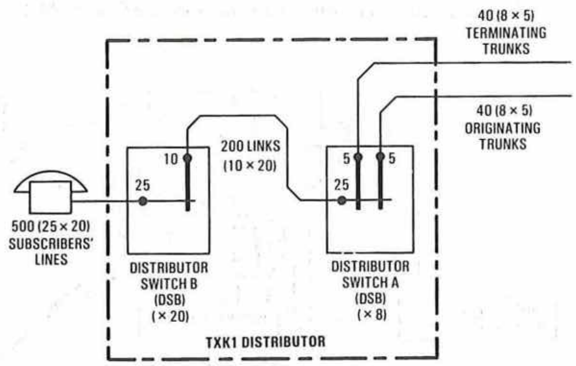
A4 If the call is to a heavily used route then a single routeing digit, or possibly two, might suffice. But, if the call is to a remote exchange on a lightly-loaded traffic route, then the call may be set up via a tandem exchange, and this necessitates the use of more routeing digits.

Q5 *Which item of equipment provides transmitter current to the calling customer in a call from a Strowger non-director exchange to an adjacent exchange.*

A5 The auto-to-auto relay-set provides transmitter current to the calling customer.

Q6 *Draw a block diagram of a line distributor stage in a TXK1 exchange showing typical switch quantities.*

A6



Q7 *State the type of relay used in a capacitor-type transmission bridge, giving reasons.*

A7 High impedance relays are used in a capacitor-type transmission bridge. They provide a high impedance to speech currents and, therefore, the shunt loss on the transmission path is kept to a minimum. Also, speech currents are kept away from the central exchange battery, and this prevents overhearing.

Q8 *State the function of the D-switch in a TXE2 reed-relay exchange.*

A8 The function of the D-switch is to prevent internal blocking. The D-switch gives access to 5 C-switches, and, therefore, increases the number of routes between the supervisory relay-set and the required customer.

Q9 *State*

(*a*) *The free condition in a battery testing circuit.*
(*b*) *The busy condition in a battery testing circuit.*
(*c*) *The free condition in an earth testing circuit.*
(*d*) *The busy condition in an earth testing circuit.*

A9 (*a*) A specific battery potential.
(*b*) Earth or absence of specified potential.
(*c*) A disconnection.
(*d*) A full earth.

Q10 *State which levels of a first selector carry the heaviest traffic, giving reasons.*

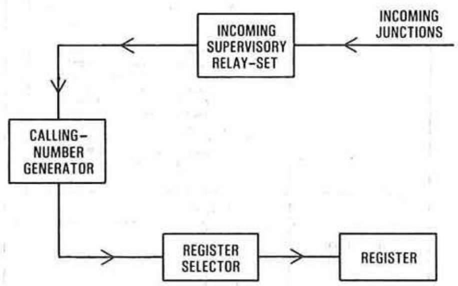
A10 The lower levels. By allocating the busiest routes to the lower selector levels, wear and tear on mechanisms are reduced to a minimum.

SECTION B

Q11 *(a) With the aid of a block diagram, explain how an incoming terminating call is established at a TXE2 reed-relay exchange.*

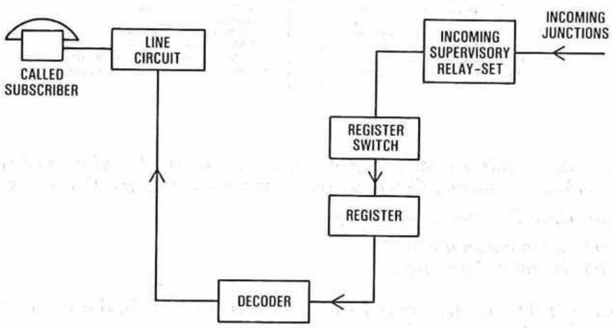
(b) With the aid of a diagram, explain how a crosspoint is operated in a TXE2 exchange.

A11 (*a*) Each incoming junction is terminated on an incoming supervisory relay-set (see sketch (*a*)). When an incoming call arrives, the relay-set is seized and an identifying number is generated. This number is transferred from the *calling-number generator* and stored in the allocated register in 2-out-of-5 code in the *calling-line identity store.*



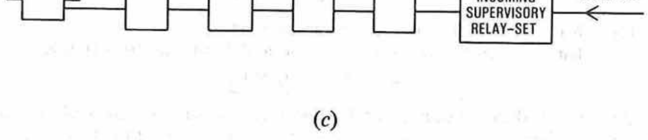
(*a*)

The generation of the incoming supervisory relay-set identity, and the allocation and connection of a register, take place during the inter-digit pause. The incoming dialled digits are then stored in 2-out-of-5 form in the register *dialled-digit store.* At the end of dialling, these digits are decoded to identify the called customer's line (see sketch (*b*)).



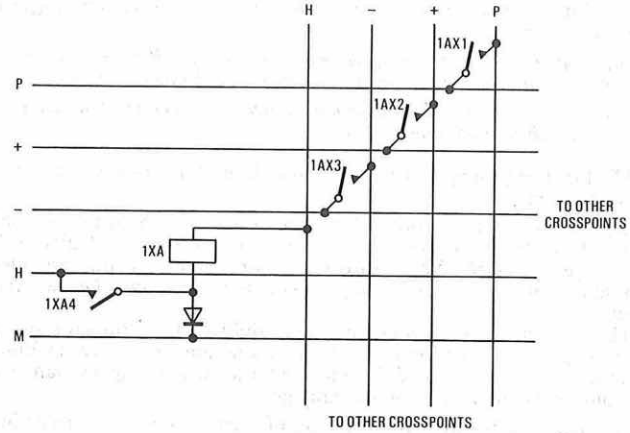
(*b*)

The called line is tested and, if free, the path between it and the incoming supervisory relay-set is established (see sketch (*c*)), and the register released.



(*c*)

(*b*) Sketch (*d*) shows the circuit of a crosspoint in a TXE2 exchange. A potential is applied by the control equipment to lead M which is connected to relay 1XA. A more positive potential is applied to lead H by the switching stage or supervisory relay-set, and this operates the relay 1XA. The P, + and − wires of the row are connected by contacts 1XA1, 1XA2 and 1XA3 to the P, + and − wires of the column. Contact 1XA4 provides a hold path for relay 1XA on wire H.

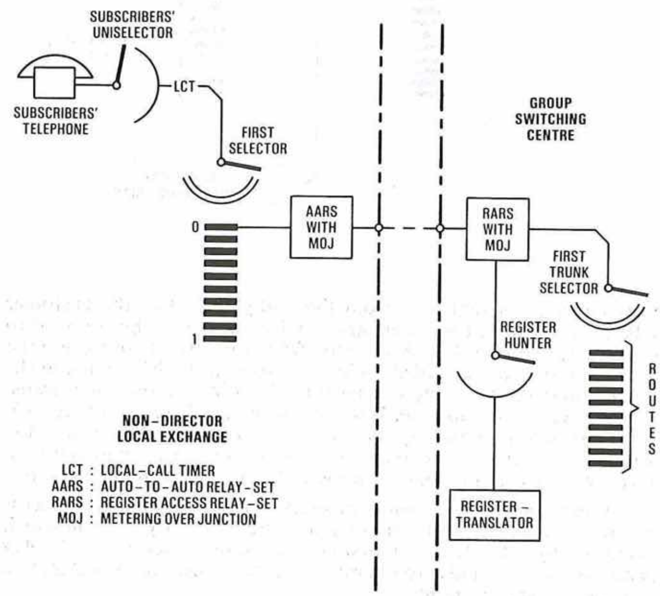


(*d*)

Q12 *(a) Explain, with the aid of a block diagram, how a customer connected to a non-director satellite exchange gets STD access. Your diagram should go as far as the trunk selector.*

(b) Having established a connection, describe how metering is effected; that is, how the calling customer's meter is activated at the predetermined tariff.

A12 (*a*) The sketch shows a block diagram of how a customer on a non-director satellite exchange gets STD access.



On receipt of dial tone the customer dials 0; that is, the first digit of an STD call. The first selector in the satellite exchange steps to level 0 and seizes an auto-to-auto relay-set associated with the STD route to the group switching centre (GSC). The register access relay-set (RARS) is seized by the incoming junction loop and activates the register hunter which hunts for, and switches to, a free register-translator (RT). Subsequent code digits are dialled into the RT, which then generates a series of routeing digits to step the trunk selectors. After receipt and storage of the numerical digits, the RT regenerates them to line. The RT and register hunter then clear down.

(*b*) Among other functions, the RT returns a *fee digit* to the RARS in accordance with the code dialled. The fee digit determines the periodicity of metering. The RARS passes the meter pulses back to the calling subscriber's meter. Because the junction is a 2-wire circuit, the signal cannot be passed over a P-wire. It is therefore done by line polarity reversals at each meter pulse.

The auto-to-auto relay-set at the originating exchange detects these reversals and converts them into positive battery pulses which are passed backwards over the P-wire to operate the calling subscriber's meter.

Q13 (*a*) *State the principal reason for providing tandem exchanges in director areas.*

(*b*) *Explain, with the aid of a diagram, how a call is routed from a customer on a director exchange to level 100 assistance services.*

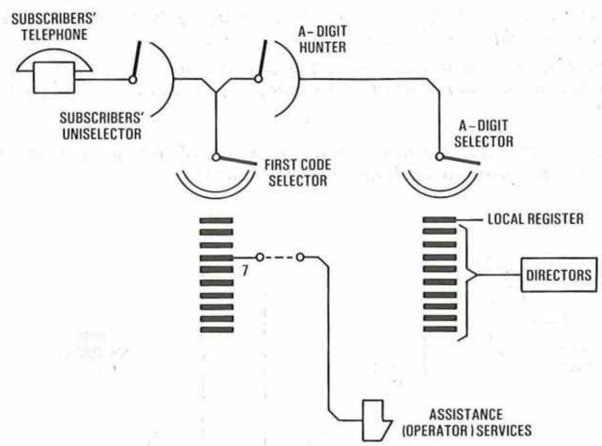
(*c*) *Describe briefly how periodic metering is achieved in an own-exchange call in a director exchange.*

A13 (*a*) The principal reasons for providing tandem exchanges in a director area are:

(*i*) Direct junction routes between exchanges are provided only when the traffic is sufficiently heavy, or when the distance between the exchanges is short. Where direct junction routes are not provided, traffic is routed via a tandem exchange, known as a *junction switching centre*.

(*ii*) Tandem exchanges enable the flexibility of the director system to be exploited. For instance, if a direct junction route became faulty, translation changes could be made at the originating exchange to re-route the call via a tandem exchange.

(*b*) The sketch shows the routeing of a call from a subscriber in a director exchange to level-100 assistance services.



After receipt of dial tone from the A-digit selector, the customer dials 1, which causes the wipers and carriage of the A-digit selector to be positioned on level 1. A director from the level 1 group is then seized. The remaining dialled digits, 00, position the BC switch in the director onto the tenth step of level 0. The director returns a translation-code digit (in this case, 7) to step the first code selector to level 7. The short-holding-time equipment then clears down leaving the customer connected to the first code selector calling the manual board. The caller receives ring tone until the call is answered by the operator.

(*c*) When the called customer answers, relay D in the final selector operates. This causes an incoming line-current polarity reversal which is detected by relay D in the first code selector. A sequence of relay operations causes a pulse to operate the calling customer's meter; this is known as *initial metering*.

At the same time, a metering circuit using a divide-by-ten (ratchet relay) device is primed. Local-call timing pulses, derived from a multiphase pulse supply, step the ratchet relay at ten times the metering rate. On the eleventh step of the ratchet relay, a meter pulse is sent to operate the calling customer's meter. This sequence continues until the call is terminated.

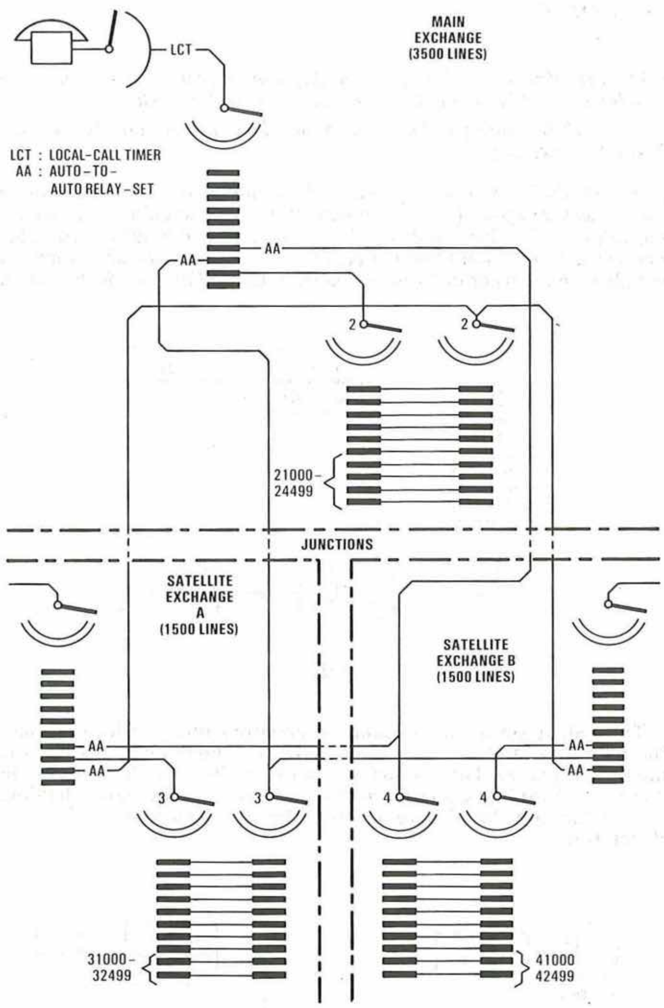
Q14 (*a*) *Define the term* LINKED NUMBERING SCHEME.

(*b*) *Given the following data, produce a numbering scheme and a trunking diagram for a non-director area. Give reasons for your decisions.*

Main exchange	*3500 lines ultimate*
Satellite A	*1500 lines ultimate*
Satellite B	*1500 lines ultimate*

A14 (*a*) A linked numbering scheme is one which is shared between several exchanges in a given area. Therefore, the same number is dialled for a particular customer irrespective of where in the given area the call is dialled from.

(*b*) The sketch shows a 5-digit numbering scheme with each exchange having an identifying first digit. This scheme avoids incoming junctions having to be terminated on final selectors.



Q15 (*a*) *A full availability group of 10 trunks is offered a total value of 4 erlangs of traffic. Calculate the traffic carried by the first trunk.*

(*b*) *Describe what is meant by:*

(*i*) *random queuing, and*
(*ii*) *disciplined queuing.*

A15 (*a*) The traffic offered to the first trunk, A_1, is the total traffic offered to the group, 4 E.

The traffic offered to the second trunk, A_2, is the traffic lost from the first trunk and is given by

$$A_2 = A_1 \times B, \qquad \ldots\ldots (1)$$

where B is the grade of service of the first trunk.

From Erlang's formula, when the number of trunks is 1, the grade of service of the first trunk is given by,

$$B = \frac{A_1}{1 + A_1}.$$

Substituting for B in equation (1),

$$\therefore \quad A_2 = A_1 \times \frac{A_1}{1 + A_1} = 4 \times \frac{4}{1+4} = 3{\cdot}2\ \text{E}.$$

Therefore, the traffic carried by the first trunk
= the total traffic offered − traffic lost from the first trunk
$= 4 - 3{\cdot}2 = \underline{0{\cdot}8\ \text{E}}.$

(*b*) (*i*) Random queuing is where calling customers are not served in any particular order. For example, random queuing occurs when a calling signal appears on a manual-board answering multiple where it is displayed at intervals along the multiple.

This calling signal competes with others for an operator's attention. Therefore, calls may not be answered sequentially.

(*ii*) Disciplined queuing occurs when the calling customer takes his place in a queue in an ordered fashion with other callers. After the first call in the queue has been answered, the remaining waiters move nearer the head of the queue until their turn arrives.

Q16 (a) With reference to a TXK1 exchange state the maximum number of calls that can be handled at any one time by the line marker.

(b) State the purpose of the start shift circuit as provided in a TXK1 exchange.

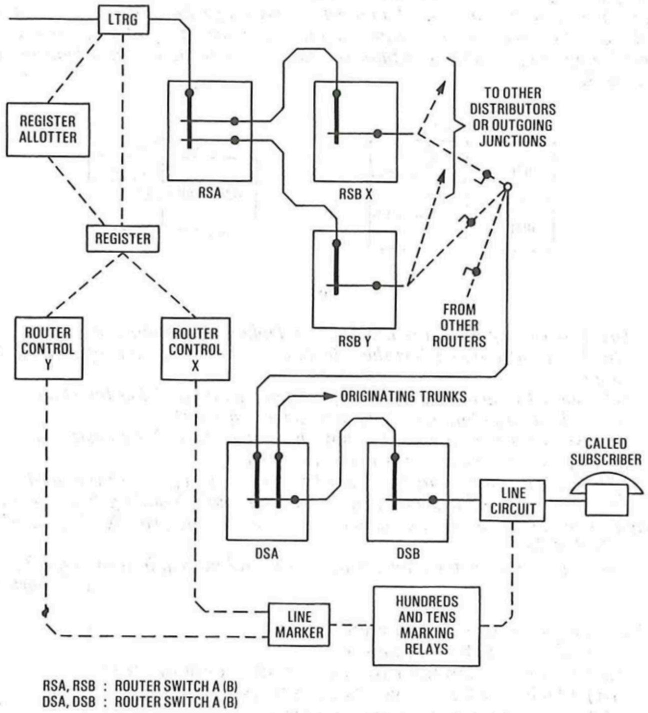
(c) Explain, with the aid of a block diagram, how the local register processes an own exchange call.

A16 (*a*) The line marker in a TXK1 exchange can handle one originating call or one terminating call, at any instant.

(*b*) The start shift circuit ensures that, for each seizure of the line marker, a new distributor switch A (DSA) is used in setting up the call through the distributor. This encourages even distribution of calls in the distributor and avoids repetitive seizure of what may be faulty equipment.

(*c*) The sketch shows the marking of the called line, and the call path from the line transmission relay group (LTRG) through the router stage and terminating distributor to the called subscriber. The dialled digits are stored in the register, and the register associates with one of the router controls (say router control X), to which it passes the called number. The router control identifies the appropriate line marker, and instructs it to mark the appropriate hundreds, tens and units leads. The hundreds and tens marking relays operate to provide access, via the line marker, to the distributor switch B (DSB) outlet, thereby permitting the line to be tested. If the line is busy or unobtainable, the router control instructs the LRTG to return the appropriate tone.

The DSB outlet to the called subscriber's line circuit is marked, as are all free inlets from DSAs. From these DSAs free-link marking signals are extended back to RSBs X in the router concerned with the call. The RSBs X return the marking signal to all the associated RSAs, but only the RSA connected to the LTRG concerned can receive the signal. The router control applies an earth to the P-wire via the register and LTRG to switch the marked RSA crosspoint. This allows the RSB X, DSA and DSB crosspoints to operate in succession, connecting the LTRG to the called line. The router control makes a continuity check of the allocated speech path and, if this is successful, the router control and register release. Ringing tone and ringing current are applied by the LTRG, which then controls the connection. If the continuity check is unsuccessful a second attempt is made to set up the connection to the called line by using the alternative path via RSBs Y.



TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

Sets of model questions and answers for Technician Education Council (TEC) units are given below. The model questions and answers reflect the types and standards of questions that may be set by colleges and answers expected, and include the styles of both in-course and end-of-unit assessments. The model questions and answers therefore illustrate the assessment procedures that students will encounter, and are useful as practise material for the skills learned during the course.

The use of calculators is permitted except where otherwise indicated.

Representative time limits or proportion of marks are sometimes shown for each question, and care has been taken to give model answers that reflect these limits. Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from the information expected of students under examination conditions.

We would like to emphasise that the model questions are not representative of questions set by any particular college.

As a general rule, questions are given in italic type and answers in upright type.

LINE AND CUSTOMER APPARATUS I 1980–81

(Students are advised to read the notes above)

Q1 At stage 1, T. Smith has a business direct exchange line at his place of residence where he acts as an import/export agent. Fig. 1 shows a plan of his main residence (building A) and an outhouse (building B). A central battery (CB) type telephone is provided in the lounge. A simplified circuit diagram of the telephone is shown in Fig. 2.

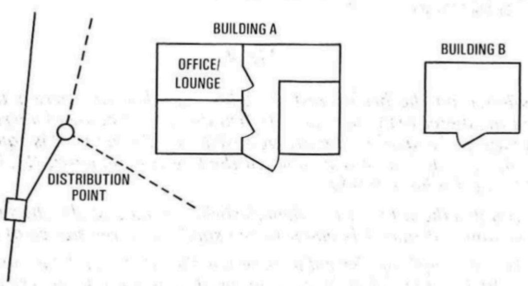


Fig. 1

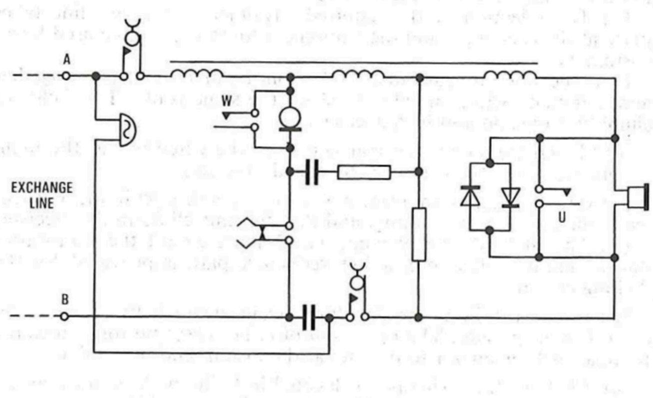


Fig. 2

At stage 2, the volume of business increases and Mr. Smith adds a small manufacturing facility by converting building B to a small workshop.

At stage 3, a further increase in business necessitates the provision of larger workshop facilities, a store and the total conversion of building A to office accommodation. A number of exchange lines are now required along with intercommunication facilities between the offices, store and workshop. Fig. 3 shows a plan of the arrangement of the premises at stage 3.

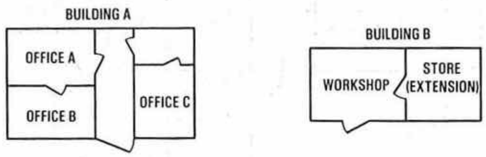


Fig. 3

(*a*) *List examples of the use of the telephone in commerce.*

(*b*) *What advantages has the telephone over other means of communication?*

(*c*) *Show by means of a sketch, the telephone provision for stage 2.*

(*d*) *Why is a public telephone exchange required?*

(*e*) *By means of a sketch, show how the stage 2 extension to the workshop is connected to the main telephone.*

(*f*) *Explain why contacts U and W, shown in Fig. 2, are required.*

(*g*) *By means of a sketch, show how internal signalling between the main telephone and the extension telephone may be provided by using a DC bell or buzzer.*

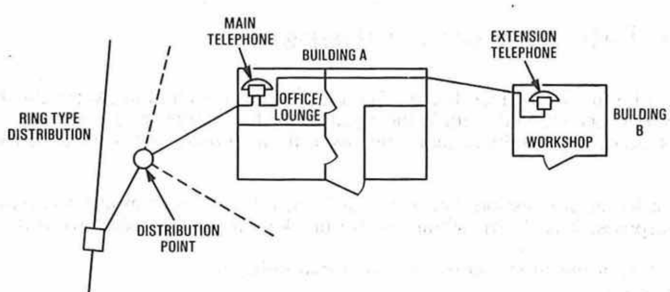
(*h*) *What type of telephone provision would be required at stage 3?*

(25 marks)

A1 (*a*) (*i*) Inter-office communication.
(*ii*) Inter-branch communication.
(*iii*) Office to shop-floor (or workshop) communication.
(*iv*) Placing orders for goods or services.
(*v*) Receiving orders from customers.
(*vi*) After-sales enquiries.
(*vii*) Market research surveys.

(*b*) (*i*) High speed.
(*ii*) Instant feedback.
(*iii*) Comparatively low cost.
(*iv*) Reasonable secrecy can be ensured.

(*c*) Sketch (*a*) shows the telephone provision at Stage 2.



(*a*)

(*d*) A public telephone exchange is required for the following reasons:

(*i*) It reduces the complexity of the public network compared with the situation where each customer's telephone is directly connected to every other customer's telephone.

(*ii*) The selection of the required customer's telephone line takes place at the exchange, and the equipment to do this can be used by all customers.

(*iii*) The lines to customers' telephones can be gathered together and combined within a cable to share the same route. This helps to simplify provision and to reduce costs.

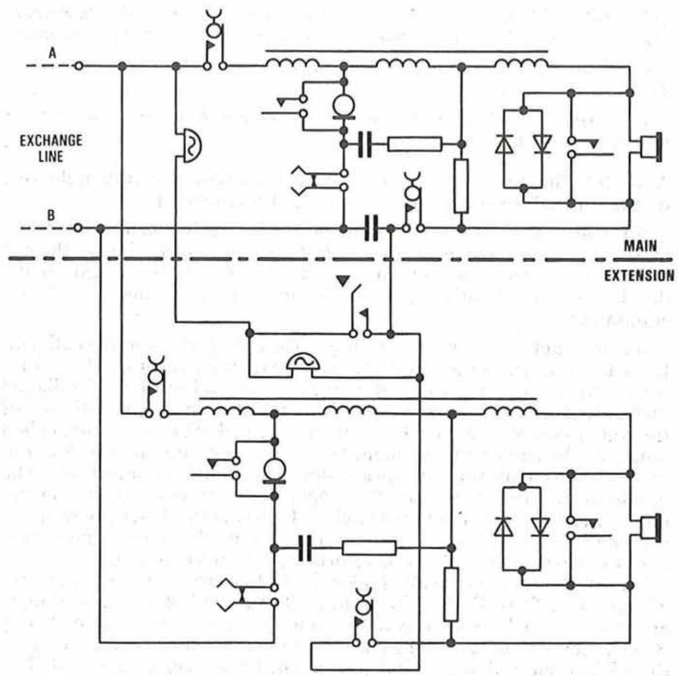
(*e*) Sketch (*b*) shows the connection of the extension to the main telephone, where the bells are connected in series.

(*f*) (*i*) The dial off-normal contacts U short circuit the receiver while the customer is dialling, and this prevents clicks in the receiver.

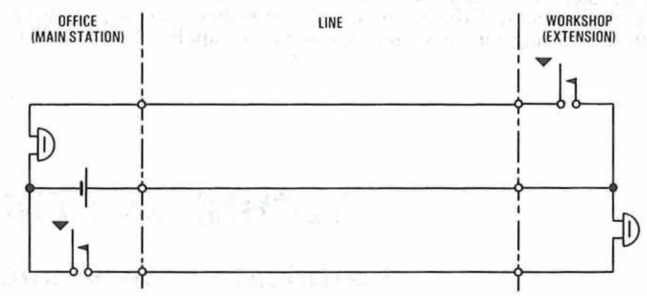
(*ii*) The dial off-normal contacts W short circuit the transmitter during dialling; therefore, a low resistance path is provided for the dialling circuit.

(*g*) Sketch (*c*) shows the signalling arrangements between main and extension telephones. The operation of either press button causes the trembler bell or buzzer to operate at the distant end of the line.

(*h*) At stage 3, a switchboard located in building A with extension telephones provided in each office, the workshop and the store, would suffice.



(*b*)



(*c*)

Q2 A conductor resistance test is being carried out on the local cable network from an exchange main distribution frame (MDF). The test equipment has been connected as shown in Fig. 4.

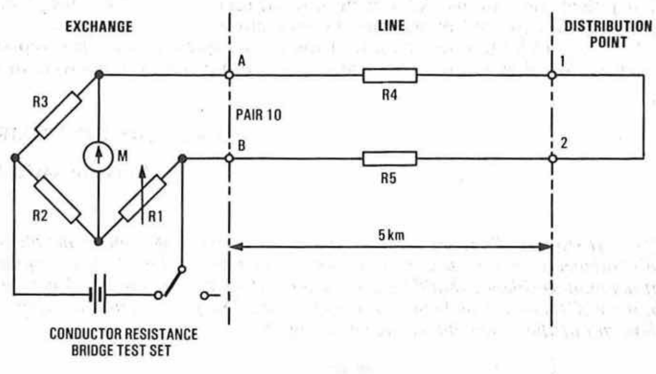


Fig. 4

A balance on the bridge test set (that is, when no current is flowing through the meter (M)) is achieved when the measured line loop resistance across pair 10 is equal to the bridge resistance R1, and R2 is equal to R3. In Fig. 4, the single-wire resistance of the line A conductor, R4, is 250 Ω, and R2, R3 are both 100 Ω.

(*a*) *What is the value of R1 when the bridge is balanced if the single-wire line resistance of line A is equal to the single-wire resistance of line B.*

(*b*) *If the length of the cable between the MDF and the distribution point (DP) is 5 km, what is the measured conductor loop resistanceper kilometre?*

(c) If the mean cable temperature rises, what effect does this have on the measured loop resistance?

(d) If a contact fault (R10) develops on pair 10 shortly after the conductor resistance test (part (a)) has been made, and the test equipment is connected as shown in Fig. 5, what is the value of R1 when the bridge is balanced, given that R6 and R7 are 200 Ω, R10 is 50 Ω, and the cable temperature is unchanged?

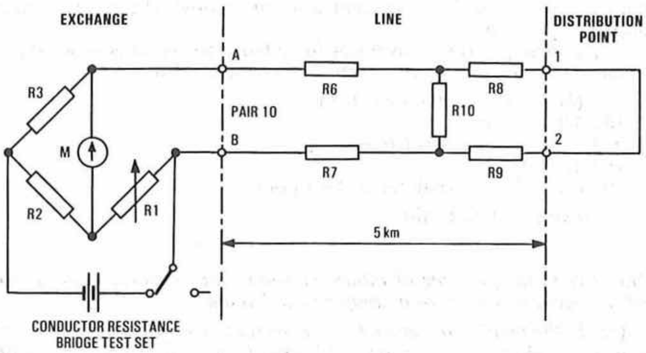
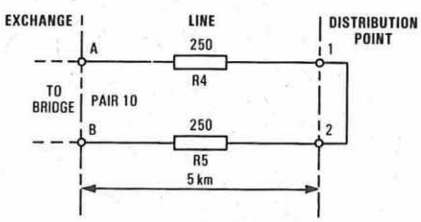


Fig. 5

(e) If the loop across terminals 1 and 2 at the DP (Fig. 5) is removed and replaced by a milliammeter which has no internal resistance, what is the measured current through R8 and R9 if the test voltage across pair 10 at the MDF is 2 V. (25 marks)

A2 (*a*) The line conditions are shown in sketch (*a*).



(*a*)

When the bridge is balanced,

R_1 = line conductor loop resistance,

$= R_4 + R_5 = \underline{500\ \Omega.}$

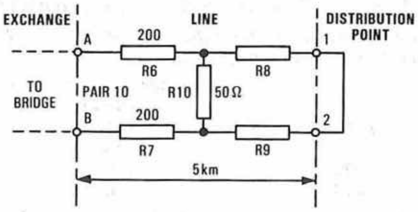
(*b*) The conductor loop resistance for the 5 km length of cable is 500 Ω.

Therefore, the conductor loop resistance per kilometre

$$= \frac{500}{5} = \underline{100\ \Omega.}$$

(*c*) If the mean cable temperature rises, then the conductor loop resistance increases.

(*d*) The line conditions with the fault resistance are shown in sketch (*b*).



(*b*)

From part (*a*), the line conductor loop resistance is 500 Ω.

$$\therefore \quad R_8 + R_9 = 500 - (R_6 + R_7),$$
$$= 500 - 400 = 100\ \Omega.$$

But, the value of R_{10} in parallel with R_8 and R_9,

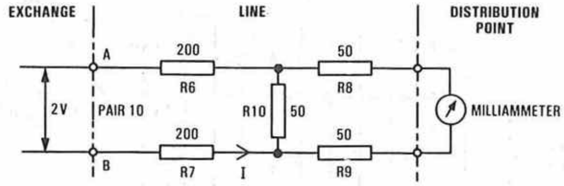
$$= \frac{50 \times 100}{50 + 100} = \frac{5000}{150} = 33 \cdot 33\ \Omega.$$

Therefore, with the fault condition, the line conductor loop resistance

$$= 400 + 33 \cdot 33 = 433 \cdot 33\ \Omega.$$

$$\therefore \quad R_1 = \underline{433 \cdot 33\ \Omega.}$$

(*e*) The line with the milliammeter inserted is shown in sketch (*c*).



(*c*)

$$\text{Now,} \quad I = \frac{2}{433 \cdot 33}\ \text{A} = \frac{2}{433 \cdot 33} \times 1000\ \text{mA} = 4 \cdot 62\ \text{mA}.$$

But, the current through R10 is twice the current flowing through R8 and R9. Therefore, the current flowing through R8 and R9

$$= \frac{4 \cdot 62}{3} = \underline{1 \cdot 54\ \text{mA.}}$$

Q3 *(a) Draw a simplified circuit diagram of a cord circuit which provides supervisory facilities by means of lamps.*

(b) State the main disadvantage of cord-type switchboards.

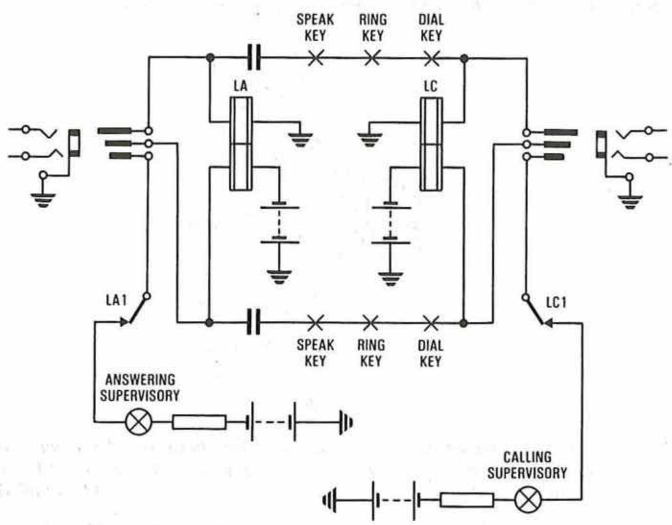
(c) A cordless switchboard (not necessarily one in current use) which uses key-type co-ordinate switching has 9 extension circuits, 5 connecting circuits, and 36 three-position keys (with centre OFF position) arranged in the standard layout. The number of keys excludes the keys that are used for alarm and night services, and the operator's circuit.

Calculate

(i) the number of exchange lines, and

(ii) the number of crosspoints. (15 marks)

A3 (*a*) Sketch (*a*) shows a simplified circuit diagram of a cord circuit providing supervisory facilities by means of lamps.



(*a*)

(*b*) The main disadvantage of cord-type switchboards is their fault liability.

(*c*) Sketch (*b*) illustrates the information supplied in the question.

The total number of crosspoints required, *X*, is the number of connecting circuits multiplied by the total number of extensions and exchange lines.

Thus, $\quad X = 5 \times (9 + N) = 45 + 5N,$

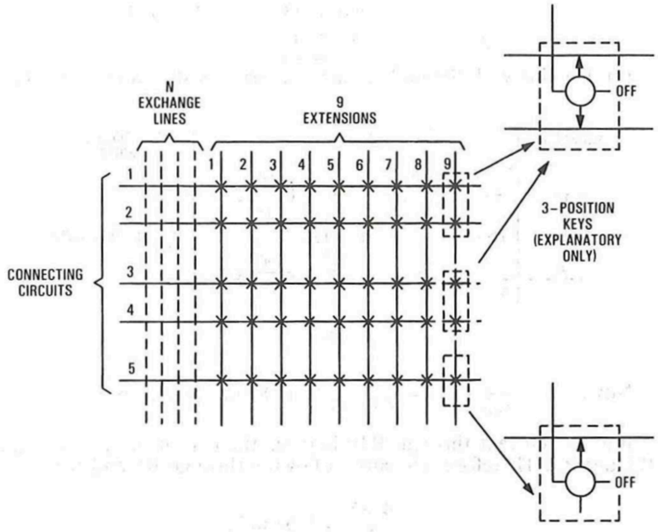
where *N* is the number of exchange lines.

For each circuit, three 3-position keys are needed.

$$\therefore \quad 9 + N = \frac{36}{3} = 12.$$

$$\therefore \quad \underline{N = 3,}$$

and, $\quad \underline{X = 45 + 5 \times 3 = 60.}$



(*b*)

Q4 (*a*) *Draw a circuit diagram of a simple local battery (LB) telephone system that provides intercommunication facilities between 2 locations spaced at a cable distance of 50 m apart, and that uses only the telephone components listed below.*

The telephone components are:

4 gravity switches	*2 capacitors (2 μF)*
2 carbon transmitters	*2 AC generators (17 Hz)*
2 receivers	*2 LB telephone transformers*
2 primary batteries (3 V)	*4 change-over springsets*
60 m single-pair PVC covered cable	*2 AC bells*

(*b*) *State the major disadvantage of an LB telephone system.*

(*c*) *List 3 functions of the transformer in a simple LB telephone circuit.*

(*d*) *Fig. 6 shows a simplified diagram of a carbon granule type transmitter. Identify the lettered components of the transmitter.*

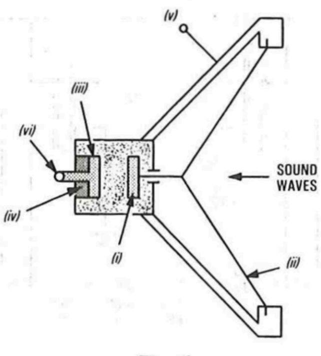
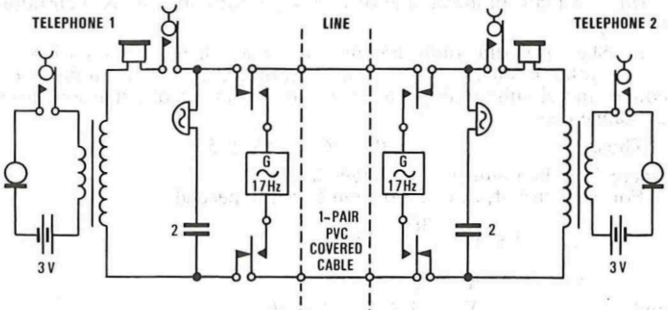


Fig. 6

(*e*) *State, in general terms, the relationship between the electrical resistance of the carbon granules in a telephone transmitter and the pressure applied to them.* (*15 marks*)

A4 (*a*) The sketch shows how the components given could be interconnected to provide a simple LB telephone system.



(*b*) The major disadvantage of an LB telephone system is the need to maintain a battery at every customer's premises.

(*c*) The 3 main functions of the transformer are:

(*i*) It separates the transmitter circuit from the line, thus ensuring that there is a low resistance circuit for the transmitter. This allows adequate current to be obtained from a low voltage battery.

(*ii*) It isolates the receiver from the direct current that flows through the transmitter. A direct current flowing through the receiver would impair its efficiency.

(*iii*) It matches the transmitter impedance to the line impedance to ensure that the maximum speech signal is sent to line.

(*d*) (*i*) Moving carbon electrode.
(*ii*) Diaphragm.
(*iii*) Fixed carbon electrode.
(*iv*) Insulation.
(*v*) and (*vi*) External connection points.

(*e*) Inverse relationship.

Q5 (*a*) *In the planning of future telecommunications needs in an area, when should a development study be carried out?*

(*b*) *If the number of tenancies in a section of an exchange area is 50 and the number of connections is 40, what is the value of the penetration factor (PF)?*

(*c*) *How are the boundaries of a section determined?*

(*d*) *Fig. 7 shows a particular section of an exchange area. If 8 tenancies are expected in a planned development to be commenced in 1985, complete the development triangle.*

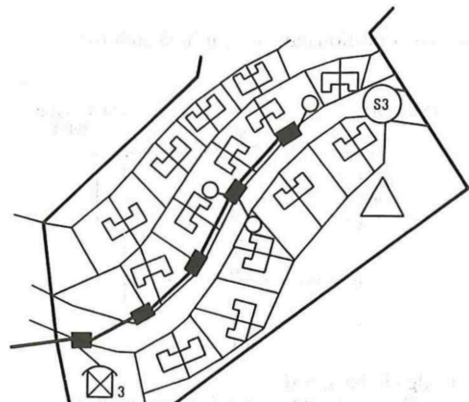


Fig. 7

(*e*) *What type of distribution has been provided in the part of section 3 shown in Fig. 7.*

(*f*) *How much plant should be provided on the distribution side, and is an economic planning period used?*

(*g*) *By means of a simple diagram, identify and locate local exchange cable and flexibility points.*

(*h*) *What 2 factors affect the length of the economic planning period?*

(*i*) *The table below shows the total section forecast. Show, by means of a graph, the trend of demand growth.*

Year	*Number of connections*
1975	*180* (*Existing forecast*)
1980	*265*
1985	*365*
1990	*480*
1995	*580*

(*j*) *If a 250-pair cable exists, in which year is it exhausted?*

(*k*) *If a 350-pair cable is installed when the existing cable is exhausted, what is the length of the economic planning period?*

(*l*) *If a number of new cables were available when the existing cable was exhausted, what factors would influence the choice of cable size?* (*20 marks*)

A5 (*a*) A development study is necessary

(*i*) when the growth of customer demand for service is out of line with the existing forecast, and

(*ii*) when the normal area environment has changed due to new housing estates, demolition of property, change of ownership etc.

(*b*) The penetration factor $= \dfrac{\text{number of connections}}{\text{number of tenancies}} = \dfrac{40}{50} = \underline{0 \cdot 8.}$

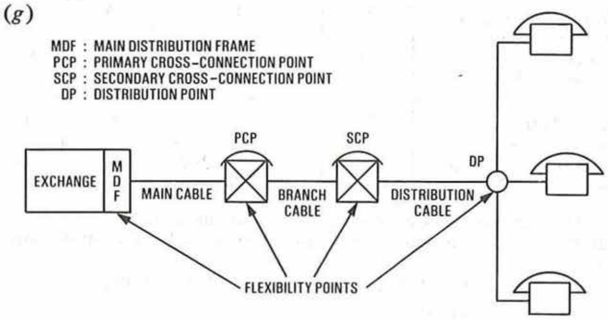
(*c*) The boundaries of a section are drawn so that all the dwellings within the section are considered to have uniform telephone potential.

(*d*)

(*e*) Overhead distribution.

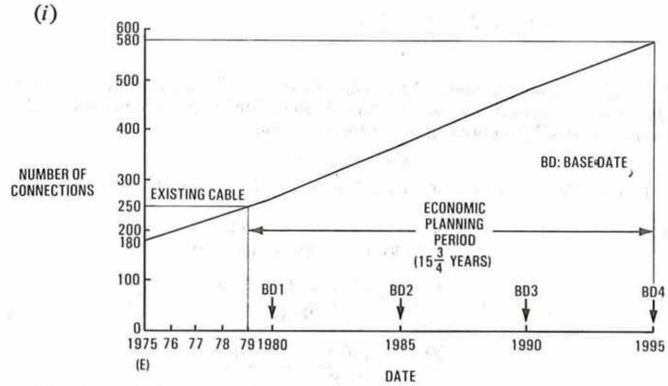
(*f*) Sufficient plant to cover the 20-year forecast. An economic planning period is not used.

(*g*)



(*h*) The economic planning period is affected by the rate of growth in demand for service and the type of plant provided.

(*i*)



(*j*) The existing cable is exhausted in 1979.

(*k*) The length of the economic planning period is $15\frac{3}{4}$ years.

[*Note*: A total of 580 pairs is sufficient to meet the needs for the whole of the planning period which ends in 1995.]

(*l*) The factors which influence the size of the new cable installed are:

(*i*) installation costs,
(*ii*) depreciation,
(*iii*) maintenance costs,
(*iv*) interest rates, and
(*v*) available duct space.

MATHEMATICS II 1980–81

(Students are advised to read the notes on p. 25)

Q1 Use the substitution method to solve the following equations

(*a*)
$$3x + 2y = 5,$$
$$x + y = 2.$$

(*b*)
$$\frac{a}{4} + \frac{b}{3} = 12$$
$$\frac{a}{8} - \frac{b}{6} = 0$$

A1 (*a*)
$$3x + 2y = 5 \qquad \ldots\ldots (1)$$
$$x + y = 2. \qquad \ldots\ldots (2)$$

From equation (2), $x = 2 - y$.

Substituting for x in equation (1):
$$3(2 - y) + 2y = 5.$$
$$6 - 3y + 2y = 5.$$
$$\therefore \quad \underline{y = 1.}$$
$$\therefore \quad \underline{x = 1.}$$

(*b*)
$$\frac{a}{4} + \frac{b}{3} = 12. \qquad \ldots\ldots (1)$$
$$\frac{a}{8} - \frac{b}{6} = 0. \qquad \ldots\ldots (2)$$

From equation (2) $\quad \dfrac{a}{8} = \dfrac{b}{6}.$

$$\therefore \quad a = \frac{8b}{6} = \frac{4b}{3}.$$

Substituting for a in equation (1):
$$\frac{4b}{12} + \frac{b}{3} = 12.$$
$$\therefore \quad \underline{b = 18.}$$
$$\therefore \quad \frac{a}{8} = \frac{18}{6} = 3.$$
$$\therefore \quad \underline{a = 24.}$$

Q2 The application of Kirchhoff's laws to an electrical circuit produces the following equations
$$3 \cdot 0 = 0 \cdot 2I_1 + (I_1 - I_2),$$
$$-4 \cdot 0 = 0 \cdot 1I_1 - (I_1 - I_2).$$
What are the values of I_1 and I_2?

A2
$$3 \cdot 0 = 0 \cdot 2I_1 + (I_1 - I_2). \qquad \ldots\ldots (1)$$
$$-4 \cdot 0 = 0 \cdot 1I_1 - (I_1 - I_2). \qquad \ldots\ldots (2)$$

Equation (1) becomes
$$3 \cdot 0 = 0 \cdot 2I_1 + I_1 - I_2,$$
$$= 1 \cdot 2I_1 - I_2. \qquad \ldots\ldots (3)$$

Equation (2) becomes
$$-4 \cdot 0 = 0 \cdot 1I_1 - I_1 + I_2,$$
$$= -0 \cdot 9I_1 + I_2. \qquad \ldots\ldots (4)$$

Adding equations (3) and (4) gives
$$-1 \cdot 0 = 0 \cdot 3I_1.$$
$$\therefore \quad \underline{I_1 = -3 \cdot 33 \text{ A.}}$$

Substituting for I_1 in equation (3) gives
$$3 \cdot 0 = -4 \cdot 0 - I_2.$$
$$\therefore \quad \underline{I_2 = -7 \text{ A.}}$$

Q3 What quadratic expression is equal to the product of $(2x - 3)$ $(3x + 4)$.

A3 $\quad 6x^2 - x - 12.$

Q4 Form the quadratic equation whose roots are 4 and 5.

A4 The equation is $(x - 4)(x - 5) = 0$; that is, $x^2 - 9x + 20 = 0$.

Q5 What are the roots of the equation $2x^2 - 18 = 0$?

A5 $\quad x = 3$ and $x = -3$.

Q6 Solve the equation
$$1 \cdot 4a^2 + 3 \cdot 6a = 2 \cdot 5$$

A6
$$a = \frac{-3 \cdot 6 \pm \sqrt{\{3 \cdot 6^2 - [4 \times 1 \cdot 4 \times (-2 \cdot 5)]\}}}{2 \times 1 \cdot 4},$$
$$= \frac{-3 \cdot 6 \pm \sqrt{(12 \cdot 96 + 14)}}{2 \cdot 8},$$
$$= \frac{-3 \cdot 6 \pm \sqrt{(26 \cdot 96)}}{2 \cdot 8},$$
$$= \frac{-3 \cdot 6 \pm 5 \cdot 19}{2 \cdot 8},$$

$= \underline{-3{\cdot}14 \text{ or } -0{\cdot}57.}$

Q7 The distance (s metres) travelled by a body having an initial velocity of u metres/second in time t seconds and having an acceleration of a metres/second² is represented by the equation

$$s = ut + \tfrac{1}{2}at^2.$$

If $u = 20$ m/s, $a = -9{\cdot}81$ m/s² and $s = 15$ m, find t.

A7

$$15 = 20t - \tfrac{1}{2} \times 9{\cdot}81t^2.$$

$$\therefore \quad 4{\cdot}905t^2 - 20t + 15 = 0.$$

$$\therefore \quad t = \frac{20 \pm \sqrt{(20^2 - 4 \times 4{\cdot}905 \times 15)}}{9{\cdot}81},$$

$$= \frac{20 \pm \sqrt{(400 - 294{\cdot}3)}}{9{\cdot}81},$$

$$= \frac{20 \pm \sqrt{105{\cdot}7}}{9{\cdot}8},$$

$$= \frac{20 \pm 10{\cdot}28}{9{\cdot}8},$$

$$= \underline{3{\cdot}09 \text{ s or } 0{\cdot}99 \text{ s.}}$$

Q8 Using tables, find the logarithms of the following numbers.

(*a*) *6·54* (*b*) *65·43*
(*c*) *165·4* (*d*) *0·65*

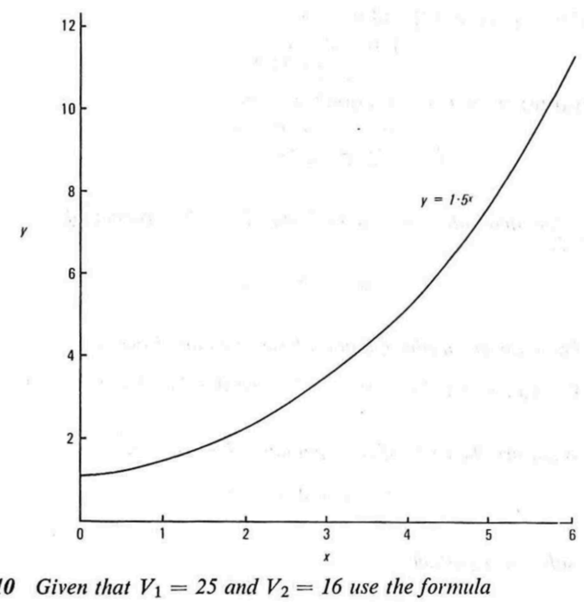
A8 (*a*) 0·8156 (*b*) 1·8158
(*c*) 2·2185 (*d*) $\bar{1}{\cdot}8129$

Q9 Plot the graph of $y = 1{\cdot}5^x$ for values of x from 0 to 6.

A9 The graph may be plotted from the following table.

x	0	1	2	3	4	5	6
y	1	1·5	2·25	3·375	5·06	7·59	11·39

The graph is shown in the sketch.



Q10 Given that $V_1 = 25$ and $V_2 = 16$ use the formula

$$10 \log_{10} \frac{P_1}{P_2} = 20 \log_{10} \frac{V_1}{V_2}$$

to calculate the ratio P_1/P_2.

A10

$$20 \log_{10} \frac{V_1}{V_2} = 20 (\log_{10} V_1 - \log_{10} V_2),$$

$$= 20 (\log_{10} 25 - \log_{10} 16),$$
$$= 20 (1{\cdot}3979 - 1{\cdot}2041),$$
$$= 20 \times 0{\cdot}1938,$$
$$= 3{\cdot}876.$$

$$\therefore \quad \log_{10} \frac{P_1}{P_2} = 0{\cdot}3876.$$

$$\therefore \quad \frac{P_1}{P_2} = \text{antilog}_{10}\, 0{\cdot}3876,$$

$$= \underline{2{\cdot}443.}$$

Q11 The depth of a ditch measured at intervals from one side are shown in the Table. Use the mid-ordinate rule to determine the cross-sectional area of the ditch.

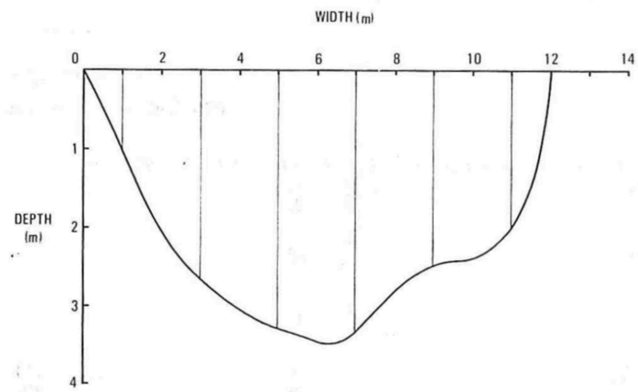
Distance (m)	*0*	*1*	*2*	*3*	*4*	*5*	*6*
Depth (m)	*0*	*1·0*	*2·1*	*2·7*	*3·1*	*3·3*	*3·5*

Distance (m)	*7*	*8*	*9*	*10*	*11*	*12*
Depth (m)	*3·35*	*2·8*	*2·5*	*2·4*	*2·0*	*0*

A11 The "graph" of the ditch is shown in the sketch.

Taking 6 intervals each 2 m wide, the area by the mid-ordinate rule is

$$2(1{\cdot}0 + 2{\cdot}7 + 3{\cdot}3 + 3{\cdot}35 + 2{\cdot}5 + 2{\cdot}0),$$
$$= 2 \times 14{\cdot}85,$$
$$= \underline{29{\cdot}7 \text{ m}^2.}$$



Q12 Use tables of natural logarithms to evaluate

(*a*) *ln 75·35,*
(*b*) *ln 0·007535, and*
(*c*) *ln 7535.*

A12 (*a*) $\ln 75{\cdot}35 = \ln 7{\cdot}535 + \ln 10^1,$
$= 2{\cdot}0196 + 2{\cdot}3026,$
$= \underline{4{\cdot}3222.}$

(*b*) $\ln 0{\cdot}007535 = \ln 7{\cdot}535 + \ln 10^{-3},$
$= 2{\cdot}0196 + \bar{7}{\cdot}0922,$
$= \underline{\bar{5}{\cdot}1118.}$

(*c*) $\ln 7535 = \ln 7{\cdot}535 + \ln 10^3,$
$= 2{\cdot}0196 + 6{\cdot}9078,$
$= \underline{8{\cdot}9274.}$

Q13 Two points on a graph have the co-ordinates (4, 6) and (6, 12). Calculate the average slope of the curve between these points.

A13 $\text{Slope} = \dfrac{12 - 6}{6 - 4} = \dfrac{6}{2} = \underline{3.}$

Q14 Differentiate from first principles $y = x^3$.

A14 Let x increase by a small amount h.

$$\therefore \quad \frac{dy}{dx} = \lim_{h \to 0} \frac{f(x + h) - f(x)}{x + h - x}.$$

In this case $f(x) = x^3$.

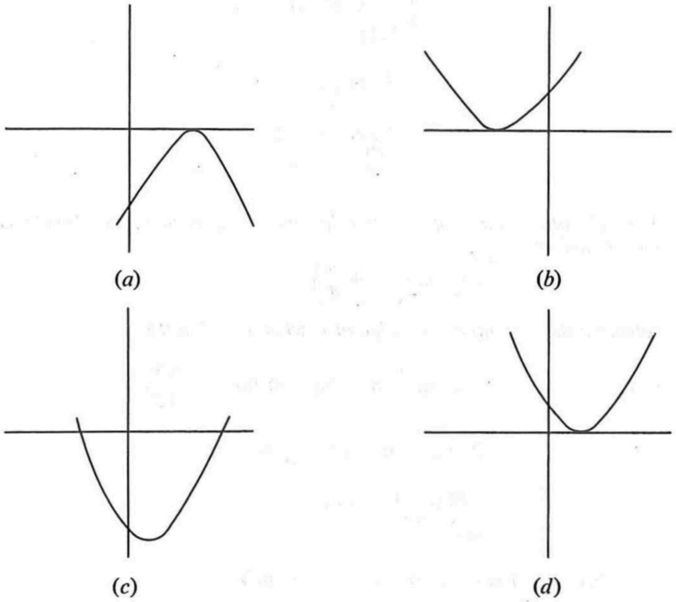
$$\therefore \quad f(x + h) = (x + h)^3 = x^3 + 3hx^2 + 3h^2x + h^3.$$

$$\therefore \quad \frac{dy}{dx} = \lim_{h \to 0} \frac{x^3 + 3hx^2 + 3h^2x + h^3 - x^3}{h},$$

$$= \lim_{h \to 0} 3x^2 + 3hx + h^2,$$

$$= \underline{3x^2.}$$

Q15 Which of the following graphs represent $y = x^2 - 2x + 1$?



A15 (*d*).

Q16 Differentiate the following expressions

(*a*) $y = \frac{1}{4}x^4$, (*b*) $y = \frac{1}{3x}$, *and* (*c*) $y = \frac{1}{2x^3}$.

A16 (*a*) x^3. (*b*) $-\frac{1}{3x^2}$. (*c*) $-\frac{3}{2x^4}$.

Q17 Find the values of x at which the following functions have stationary points, and determine whether they are maxima or minima.

(*a*) $y = x^2 - 4x + 3$
(*b*) $y = x^3 - 5x^2 + 8x + 3$.

A17 (*a*)
$$\frac{dy}{dx} = 2x - 4.$$

At a stationary point $\frac{dy}{dx} = 0$.

$$\therefore \quad 2x - 4 = 0.$$
$$\therefore \quad \underline{x = 2.}$$

$$\frac{d^2y}{dx^2} = 2.$$

Since this is positive, the function $y = x^2 - 4x + 3$ has a minimum value at $x = 2$.

(*b*)
$$\frac{dy}{dx} = 3x^2 - 10x + 8.$$

This equals zero when $x = \underline{\frac{4}{3}}$ or $\underline{2.}$

$$\frac{d^2y}{dx^2} = 6x - 10.$$

When $x = 2$, $\frac{d^2y}{dx^2} = +2$.

Therefore, $x^3 - 5x^2 + 8x + 3$ has a minimum value when $x = 2$.

When $x = \frac{4}{3}$, $\frac{d^2y}{dx^2} = 8 - 10 = -2$.

Therefore $x^3 - 5x^2 + 8x + 3$ has a maximum value when $x = \frac{4}{3}$.

Q18 Plot the graph of $f(x) = x^2 + x$ between $x = 0$ and $x = 3$. Determine the rate of change of $f(x)$ with respect to x at $x = +2$.

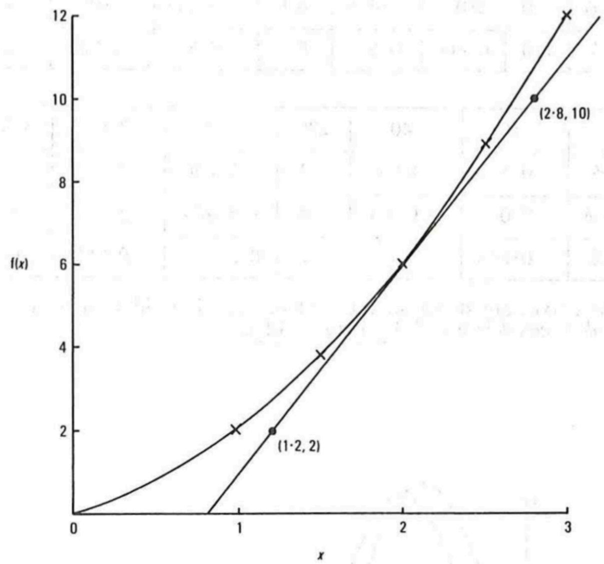
A18 The graph may be plotted from the following table.

x	0	0·5	1	1·5	2·0	2·5	3
$f(x)$	0	0·75	2	3·75	6	8·75	12

The graph is shown in the sketch.

Drawing a tangent at $x = 2$, the rate of change of $f(x)$ with respect to x is slope of the tangent; that is,

$$\frac{10 - 2}{2{\cdot}8 - 1{\cdot}2} = \frac{8}{1{\cdot}6} = \underline{5.}$$



Q19 If $y = \sin\theta + \cos\theta$ find

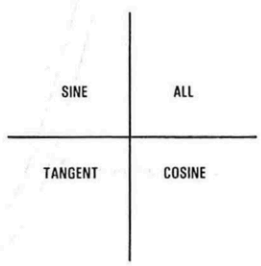
(*a*) $\frac{dy}{d\theta}$ *and* (*b*) $\frac{d^2y}{d\theta^2}$

A19 (*a*)
$$\frac{dy}{d\theta} = \cos\theta - \sin\theta$$

(*b*)
$$\frac{d^2y}{d\theta^2} = -\sin\theta - \cos\theta$$

Q20 Draw a diagram to show which of ratios sine, cosine and tangent are positive in each quadrant.

A20



Q21 Evaluate the following
(*a*) *sin 145°*, (*b*) *cos 145°*, *and* (*c*) *tan 145°*.

A21 (*a*) $\sin 145° = \sin(180–145°) = \sin 35° = \underline{0{\cdot}5736.}$

(*b*) $\cos 145° = -\cos(180° - 145°) = -\cos 35° = \underline{-0{\cdot}8191.}$

(*c*) $\tan 145° = -\tan(180° - 45°) = -\tan 35° = \underline{-0{\cdot}7002.}$

Q22 Evaluate the following
(*a*) *sec 202°*, (*b*) *cosec 202°*, *and* (*c*) *cot 202°*.

A22 (*a*) sec 202° = −sec (202° − 180°) = −sec 22° = $\underline{-1\cdot078}$.
(*b*) cosec 202° = −sec (202° − 180°) = −cosec 22° = $\underline{-2\cdot669}$.
(*c*) cot 202° = cot (202° − 180°) = cot 22° = $\underline{2\cdot475}$.

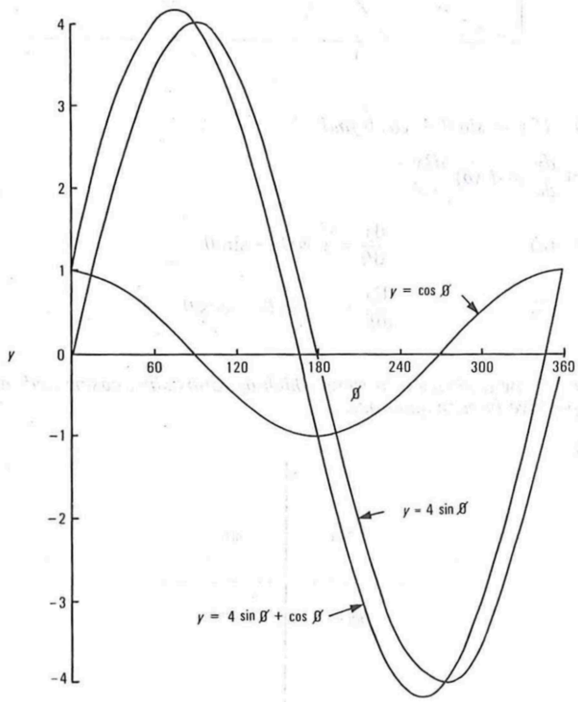
Q23 Sketch the curves of $y = 4 \sin \phi$ and $y = \cos \phi$ from $\phi = 0°$ to $\phi = 360°$ and obtain the graph of $y = 4 \sin \phi + \cos \phi$ and obtain the sinusoidal form of this function.

A23 The curves may be plotted from the following table.

ϕ	0	30	60	90	120	150	180
$\sin \phi$	0	0·5	0·866	1·0	0·866	0·5	0
$4 \sin \phi$	0	2·0	3·464	4·0	3·464	2·0	0
$\cos \phi$	1·0	0·866	0·5	0	−0·5	−0·866	−1

ϕ	210	240	270	300	330	360
$\sin \phi$	−0·5	−0·866	−1	−0·866	−0·5	0
$4 \sin \phi$	−2·0	−3·464	−4	−3·464	−2	0
$\cos \phi$	−0·866	−0·5	0	0·5	0·866	1

The curves are shown in the sketch. The sinusoidal form of $y = 4 \sin \phi + \cos \phi$ is $y = \underline{4\cdot15 \sin (\phi + 14°)}$.



Q24 Evaluate the following:
(a) $y = 4 \sin (\pi t - 1\cdot23)$ when $t = 0\cdot6$, and
(b) $y = 2\cdot3 \cos \left(\frac{\pi}{6}t + 2\cdot0\right)$ when $t = 3$.

A24 (*a*)
$$y = 4 \sin (0\cdot6\pi - 1\cdot23),$$
$$= 4 \sin (0\cdot6550),$$
$$= \underline{2\cdot436}.$$

(*b*)
$$y = 2\cdot3 \cos \left(\frac{\pi}{6} \times 3 + 2\right),$$
$$= 2\cdot3 \cos (3\cdot571),$$
$$= \underline{-2\cdot091}.$$

Q25 An alternating voltage, v volts, having a frequency of 50 Hz is represented by
$$v = 240 \sin \left(\omega t + \frac{\pi}{4}\right).$$
Calculate the instantaneous value of v when $t = 0\cdot0015$ s.

A25
$$v = 240 \sin \left(2\pi \times 50 \times 0\cdot0015 + \frac{\pi}{4}\right),$$
$$= 240 \sin \left(0\cdot4712 + \frac{\pi}{4}\right),$$
$$= 240 \sin (1\cdot2566),$$
$$= \underline{228\cdot25 \text{ V}}.$$

Q26 Prove that $\cos \theta \sqrt{(\sec^2 \theta - 1)} = \sin \theta$.

A26 Left-hand side $= \cos \theta \sqrt{(\tan^2 \theta)}$,
$$= \cos \theta \times \tan \theta,$$
$$= \cos \theta \times \frac{\sin \theta}{\cos \theta},$$
$$= \sin \theta. \qquad \text{QED}$$

Q27 Convert the following to the form $r \angle \theta°$.
(a) $3 + j2$, (b) $3 - j4$,
(c) $j6$, and (d) $-4 + j3$.
What is the sum of these 4 functions?

A27 (*a*) $3\cdot605 \angle 33\cdot69°$,
(*b*) $5 \angle -53\cdot13°$,
(*c*) $6 \angle 90°$,
(*d*) $5 \angle 143\cdot13°$.
The sum is $\underline{2 + j7}$.

Q28 Convert the following to the form $a + jb$.
(a) $3 \angle 60°$, (b) $6 \angle 245°$,
(c) $5 \angle 285°$, and (d) $2 \angle 10°$.
What is the sum of these 4 functions?

A28 (*a*) $1\cdot5 + j2\cdot598$,
(*b*) $-2\cdot536 - j5\cdot438$,
(*c*) $1\cdot294 - j4\cdot830$,
(*d*) $1\cdot970 + j0\cdot3473$.
The sum is $\underline{2\cdot228 - j7\cdot323}$.

CORRECTION

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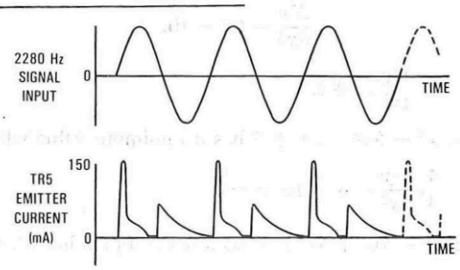
(*Supplement* Vol. 74, p. 60, January 1981)

A6 (*d*) The sketch of the emitter current waveform of transistor TR5 shown was incorrect. The corrected form of the sketch is shown opposite.



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